DESIGN AND ANALYSIS OF AN ELECTRICAL CARRIAGE

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A report submitted
in partial fulfilment of the requirements for the degree of
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2024

DECLARATION

I declare that this thesis entitled "DESIGN AND ANALYSIS OF AN ELECTRICAL CARRIAGE is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature	:	
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Date	:	14/6/2024

APPROVAL

I hereby declare that I have checked this report entitled "Design and Analysis of an Electrical Carriage", and in my opinion, this thesis fulfils the partial requirement to be awarded the degree of Bachelor of Mechatronics Engineering with Honours

Signature :

Supervisor Name : MR. MOHD BAZLI BIN BAHAR

Date : 19/6/2024

DEDICATIONS

This analysis paper is sincerely dedicated to my supportive parents who encouraged and inspired me in conducting this study. They have never left my side throughout the process and gave me strength and hope when I thought of giving this up. They provided me with a great sense of enthusiasm and perseverance to continue this. Without their love and assistance, this analysis would not have been made possible.

Moreover, I dedicate this analysis paper to my supervisor, Mr. Mohd Bazli bin Bahar, who constantly guides and teaches me to make this study even better, your guidance has not only shaped my professional growth but has also inspired me to strive for excellence. This work is a reflection of your commitment to fostering learning and development. Thank you for being an invaluable supervisor. For my family for cheering me, and my friends who have helped me in finishing this project. I appreciate your words of advice and in continuously giving me moral, emotional, and financial support.

And lastly. I dedicate this research paper to the Almighty God who gives me strength, wisdom, guidance, power of thinking, security, and competence, and for giving me good health while doing this.

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ABSTRACT

The design and analysis of an electrical carriage introduce a carriage from manually pulled carriage to motorized transportation marked a significant technological advancement, bringing about faster and more reliable modes of travel. The project aims to analyze the performance of the carriage based on speed, acceleration and energy consumption and validate the voltage measurement operation of the electric carriage vehicle's system. A thorough approach to the project included designing the electrical carriage used Fusion 360 software, strict tested to made sure the design worked and a thorough studied of performance would have tested focused on speed, acceleration, and power consumption in the electrical carriage. The UTeM Archery Range, the hill of FTKE UTeM, and Route Road FTKE are the locations of the carriage test. This research contributed significantly to understanding the complexities associated with electrical carriages, focusing on the sustainability, dependability, and safety of modern transportation. This research constitutes a substantial stride in the progression of electric vehicle technology and laid the groundwork for subsequent advancements in the domain.

ABSTRAK

Reka bentuk dan analisis beca elektrik memperkenalkan beca daripada beca yang ditarik secara manual kepada beca bermotor elektrik menandakan kemajuan teknologi, menghasilkan mod perjalanan yang lebih pantas dan lebih dipercayai. Projek ini bertujuan untuk menganalisis prestasi beca elektrik berdasarkan kelajuan, pecutan dan penggunaan tenaga dan mengesahkan operasi pengukuran voltan sistem kenderaan beca elektrik. Pendekatan menyeluruh terhadap projek itu termasuk mereka bentuk beca elektrik menggunakan perisian Fusion 360, diuji dengan ketat untuk memastikan reka bentuk berfungsi dan kajian menyeluruh tentang prestasi akan diuji tertumpu pada kelajuan, pecutan dan penggunaan kuasa dalam beca elektrik. Lapang Panah UTeM, bukit FTKE UTeM, dan Route Road FTKE merupakan lokasi ujian beca elektik. Penyelidikan ini memberikan sumbangan penting untuk memahami kerumitan yang berkaitan dengan beca elektrik, dengan tumpuan khusus pada kemampanan, kebolehpercayaan dan keselamatan pengangkutan moden. Penyelidikan ini merupakan satu kemajuan besar dalam perkembangan teknologi kenderaan elektrik dan meletakkan asas untuk kemajuan seterusnya dalam domain tersebut.

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LIST OF SYMBOLS AND ABBREVIATIONS

EV	-	Electrice vehicles
BLDC	-	Brushless DC Motor
BEV CS	-	Battery Electric Vehicle charging stations
MCB	-	Miniature Circuit Breaker

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CHAPTER 1

INTRODUCTION

1.1 Background

The background of the study, "Design and analysis of an Electrical Carriage," is firmly established in the ever-changing realm of contemporary transportation. In the current epoch marked by worldwide integration, the transport industry encounters substantial obstacles that require a fundamental change in perspective in the direction of sustainability. Conventional means of transportation, specifically those that depend on human pedal power, face constraints that hinder their effectiveness, velocity, and ability to traverse diverse landscapes. Additionally, traditional drivetrain systems, including chain or pulley mechanisms, are responsible for power dissipation and upkeep complications. Although the growing acceptance of electric vehicles presents a potentially profitable avenue, optimizing their energy efficiency and range remains the primary challenge.

1.2 Problem Statement

The problem statement for the title "Design and analysis of an Electrical Carriage" revolves around the need to address the challenges and opportunities associated with the development and evaluation of electrical carriage.

It is a complex process that involves the electrical components of the carriage frame to create and test an electrical conveyance with a motorized system. Maximizing functionality requires thinking about things like energy consumption. Understanding the behavior of linked circuits and how they change under various situations is crucial for estimating the system's robustness. The goal is to analyze an electrical carriage that not only reduces reliance on fossil fuels but also integrates an efficient and reliable motorized system for better performance and usability. This solution should consider factors such as safety, user-friendliness, and environmental impact. The challenge lies in the design, development, and demonstration of such a carriage.

Many of the electric rickshaw models now available on the market are devoid of integrated systems capable of providing thorough performance data, which is crucial for confirming and improving their efficiency and reliability. Vital parameters like power consumption, acceleration, and speed cannot be routinely observed or analyzed in the absence of a defined assessment system akin to a black box. This discrepancy makes it difficult to assess performance and impedes the development of advancements that may lead to more reliable and effective electrical carriage. In addition, the absence of a black box-like standardized assessment system makes damage more difficult to identify and repair. Without thorough performance data, it is more difficult to pinpoint the underlying causes of mistakes or inefficiencies, which raises maintenance costs and downtime.

1.3 Objective

The aim of the project title 'Design and Analysis of an Electrical carriage' assess all pertinent aspect of the electrical carriage design and operation. This includes the following;

a. To design a carriage for the electrical vehicle with an integrated electrical motorized system.

b. To validate the operation of the proposed electrical system implemented to the electric carriage vehicle's system.

c. Analyze the performance of the carriage based on speed, acceleration, battery performance and power consumption

1.4 Scope and Limitations

1. Designing an electrical carriage with an integrated motorized system using Fusion 360 software.

2. Investigating how combined circuits interact and function under diverse conditions provides a comprehensive understanding of system durability, allowing for improved design and reliability.

3. An analysis of the performance characteristics of an electrical carriage, such as speed, acceleration, power consumption, and battery performance.

4. To conduct a comprehensive analysis of an electrical carriage's performance, the testing conditions must be a straight road of approximately 100 meters to evaluate the vehicle's speed and acceleration. A hilly area with varying gradients and inclines should be selected to assess the battery performance and range.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In the past, rickshaw pullers used manual pedaling carriages to transport others. The manual pedaling carriage relies on the physical strength of individuals to move the carriage. Carriage come in different forms, however, they typically comprise a compact carriage or cart with two or three wheels, propelled, pedalled, or dragged by a human operator. The two most popular varieties of rickshaws are pulled rickshaws, in which a person pulls the cart with a harness or by hand, and cycle carriage, in which a cyclist pedals the vehicle. Cycle carriage are widely used as a cost-effective and ecologically sustainable mode of short-distance transportation in numerous Asian nations. Efforts are being made to explore alternative energy sources and energy-efficient measures for carriage, such as using solar power. Auto carriage are commonly found in developing countries due to their affordability as a mode of transportation.

With the progression of technology and the increasing global environmental consciousness, electric vehicles (EVs) have emerged as a pivotal force in revolutionizing the manner in which individuals commute. Electric vehicles, in contrast to their conventional internal combustion counterparts, derive their principal power from rechargeable batteries. The use of electric cars is directly responsible for the dramatic drop in carbon emissions. A rickshaw is a traditional three-wheeled vehicle that may be driven by a human power source or a combustion engine[1].

2.2 Fabrication

Electric vehicles (EVs) are characterized by their emphasis on fabrication, which encompasses the manufacturing and assembly processes that are involved in the construction of the many components that make up an electric vehicle. To begin, the manufacturing process involves the construction of the rickshaw's structural components, which include a platform made of steel and a body made of wood that is comfortable.[2]. For practical transportation, the project's goal is to create a portable electric car that is simple to put together and take apart[3]. Both a throttle that is located on the handlebar and a DC controller that controls a BLDC motor are responsible for propelling the vehicle forward. The manufacturing process includes a number of different components, including the establishment of the control and power distribution systems, the integration of the components of the propulsion system, and the construction of the transportation chassis.

The fabrication of the E-rickshaw using galvanized iron for the frame and body, which are welded using a mild steel 7018 electrode[4]. Additionally, the chassis frame design process made use of CAD programs like Solidworks 2020. Furthermore, to prepare for numerical analysis, Ansys software was used to model various loads and calculate equivalent stress and total deformation. These software programs and production methods ensured the structural integrity and performance of the E-rickshaw.

For the purpose of summing up, the electric rickshaw serves as a perfect illustration of how structural design, solar charging technology, and precise engineering may be used to enhance the efficiency of the manufacture of electric vehicles.

2.3 Energy provider

Energy Stored in a Lithium-ion (Li-on) Battery

For many reasons, lithium batteries have become the de facto standard in electric car technology. Rechargeable lithium batteries can store more energy per unit of area or weight due to their high energy density. This is a must-have for anybody planning to utilise electric cars or other portable electronics. Additionally, it will keep its charge for a longer time even while not in use, thanks to its lower rate of self-discharge. They are the best choice for uses requiring a higher power output because of the higher voltages they can provide[5]. Additionally, it has an extended cycle life, allowing them to undergo multiple charge and discharge cycles before performance declines[5].

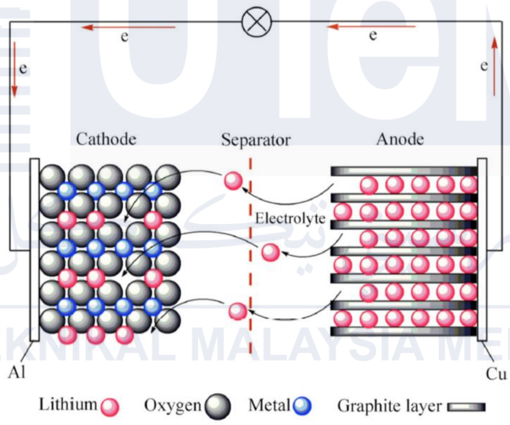


Figure 1 Schematic illustration of a lithium battery (in the case of discharge)[5]

The application of lithium batteries in electric rickshaws to increase driving range, lower maintenance needs, and boost overall efficiency[4]. The study emphasises the positive aspects of electric rickshaws that use lithium battery technology. Quicker charging periods, deeper discharges, longer operating lifespans, and lower maintenance costs are some of the advantages highlighted before.

Figure 2 Body of the the E-Rickshaw[4]

It is commonplace for electric vehicle systems to incorporate lithium batteries, the primary energy storage component of which supplies power to electric motors and propels vehicles[6]–[9]. These batteries offer high energy density, longer lifespan, faster charging times, and low self-discharge rates. The implementation of a Battery Management System (BMS) is crucial for safety, efficiency, and longevity. Lithium-ion batteries are lightweight, allowing for efficient energy storage in city cars, solar-powered vehicles, and models with in-wheel Permanent Magnet Brushless DC (PM-BLDC) motors.

Figure 3 The real chassis with battery, motor and controller[7]

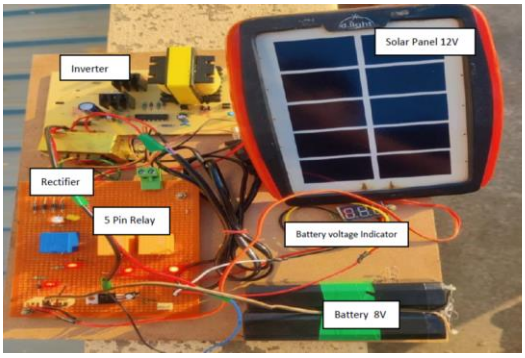


Figure 4 Hardware Prototype[8]

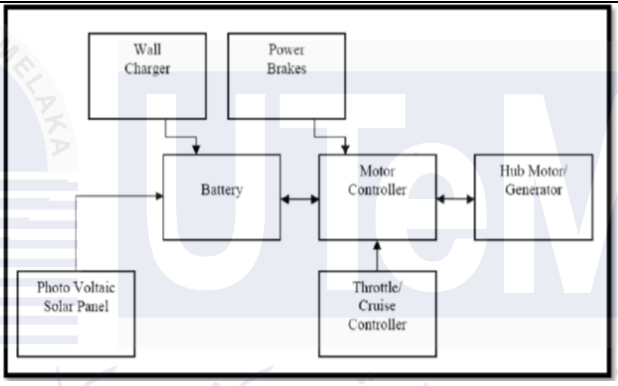


Figure 5 Block diagram for vehicle[9]

In conclusion, the greater energy density, longer cycle life, and improved performance characteristics of lithium batteries are what have led to their widespread use in electric vehicles, such as electric rickshaws. These characteristics establish lithium-ion batteries as a key technology that provides effective answers to the changing demands of modern transportation.

Energy Stored in a Fuel cell

Fuel cells have developed as an important energy provider, particularly in the context of sustainable and clean energy technology. A fuel cell is an electrochemical device that converts hydrogen and oxygen's chemical energy into electrical energy[10]. The fuel cell model utilised in the research was created by streamlining an earlier model and generates voltage as energy. The open circuit voltage, which is determined by the natural logarithm, the number of cells, the exponential voltage, and the fuel cell current, is the potential voltage generated by the fuel cell[10].

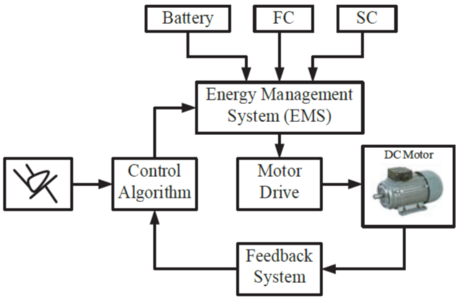


Figure 6 Multi-sources in a closed loop system for a LEV[10]

One of the primary advantages of fuel cells over batteries is that they can be refuelled rapidly and simply. However, there are currently significant obstacles preventing fuel cells from being widely used in the transportation industry, including their high cost and the absence of infrastructure for hydrogen refuelling[7]. Fuel cells can be used as an alternative energy source in BEV charging stations, providing a reliable and consistent electricity supply. They store excess energy from solar power systems in hydrogen, which can be used when solar energy production is insufficient[11]. This methodology aids in the alleviation of constraints associated with solar energy, including its intermittent and variable nature, while also augmenting the effectiveness and dependability of BEV charging stations powered by solar energy.[11].

Another author then addresses the necessity of reducing the environmental impact of conventional vehicles' use of fossil fuels. It highlights the benefits of developing environmentally friendly and pollutant-free modes of transportation, such as electric bicycles and vehicles, through the use of solar energy and battery technology. The objective is to decrease dependence on fossil fuels and mitigate environmental contamination resulting from conventional automobile emissions.[9].

In summary, fuel cells exhibit considerable potential as an energy source in BEV charging stations owing to their efficient conversion of chemical energy to electrical energy. The integration of fuel cells addresses the limitations of solar energy, thereby enhancing the reliability and effectiveness of sustainable energy applications.

Charging design

2.3.1.1 Plug-in charging design by EVs

Electric vehicles (EVs) have inspired a comprehensive investigation of the infrastructure that is necessary for EV charging. This investigation is essential for determining the efficiency, accessibility, and environmental friendliness of these forms of transportation. As a result, the design of the infrastructure for charging electric vehicles (EVs) is of great relevance since it has a direct influence on the degree to which EVs can integrate into the transportation networks of the modern day. An investigation was conducted to determine the benefits and drawbacks of electric vehicle (EV) charging for electric power.[12]. The electrical services that could be rendered possible through regulated EV charging and discharging were emphasized as positive outcomes. This study provides significant insights into the impact of electric vehicle charging on power systems, which are crucial for understanding the integration of EVs into the power grid[12].

The author in [11] use of both AC and DC charging at charging facilities for battery electric vehicles (BEVs) is discussed. DC charging in BEV charging stations (Battery Electric Vehicle charging stations) is accomplished through the use of an AC-DC converter or rectifier within the charger. AC power is the more prevalent charging method for BEVs.. DC charging is generally faster and more efficient compared to AC charging.

Table 1 parameter of conventional BEV cs[11]

Parameters	Conventional BEV CS
RES	Depends
Availability	99–100%, depends on the power grid
Stability	High stability
Carbon emission	Yes, during electricity generation from non-RES
The need for battery storage	Depending on the design
Off-grid and on-grid	Only on-grid because off-grid is not capable of generating own electricity
Scalability	Yes
Blockchain-enabled	Yes

Next, [13] the charging of electric vehicles (EVs) and the factors that influence the charging load in different areas of the distribution network. It analyzes the fixed factors affecting the charging load of EVs, such as the type of EV and charging equipment, and considers the behavior characteristics and psychological factors of EV users as random factors influencing the charging load. The paper also models the EV charging load in residential, industrial, and commercial areas, as well as at charging stations, using Monte Carlo simulation. The established model provides insights into the impact of large-scale charging on the power grid and offers reference for the suppression of voltage fluctuation in the distribution network.

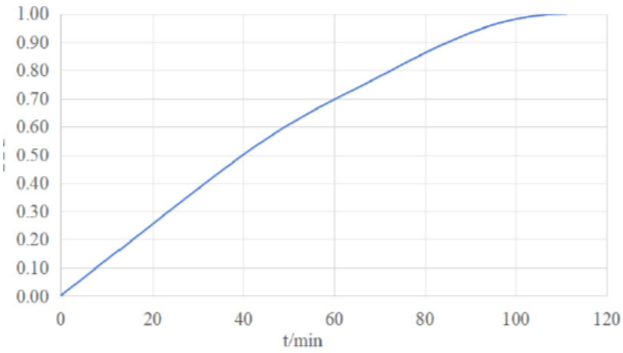


Figure 7 curve of BEV fast charging[13]

These resources offer a comprehensive review of the literature on the power design of a new five-wheel electric vehicle (EV), covering subjects such safety features, grid load modelling, EV charging effects on power systems, and reliability concerns.

2.3.1.2 Wireless charging design by Evs

Significant advancements have been achieved by electric vehicles (EVs) since the advent of wireless charging technology, which is revolutionizing the traditional charging infrastructure approach. By eliminating the need for physical connectors, wireless electric vehicle (EV) charging technology introduces a novel era of efficiency and usability in charging solutions. In recent years, a number of studies have been devoted to enhancing the performance and efficacy of wireless charging for electric vehicles.[14][15][16]. The efficacy of wireless charging systems for electric vehicles (EVs) is investigated in this study.

Wireless energy transfer from a charging station to the receiver unit of an electric vehicle is what the term "wireless" primarily refers to[14]. During the charging process, the elimination of the need for the presence of physical cables is accomplished by the utilization of wireless power transfer using inductive coupling to accomplish this. The fundamental purpose of this wireless charging approach is to ensure the safety of the battery while simultaneously simplifying and improving the process of charging an electric vehicle[14].

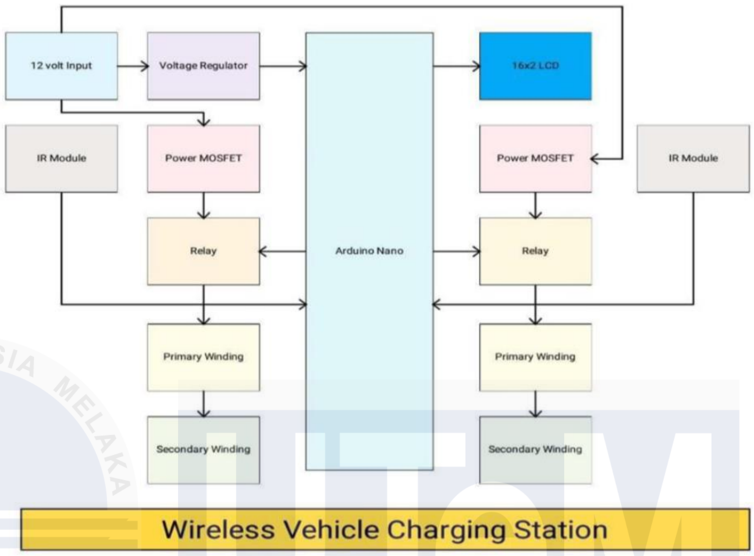


Figure 8 Flow Diagram

Recent studies have placed a great deal of emphasis on the effectiveness of wireless charging systems[15]. The effects of coil design, inductance, and electromagnetic coupling on charging efficiency have been investigated in research with the goal of enhancing the overall effectiveness of wireless charging systems for electric cars using electromagnetic coupling. Control solutions have also been proposed for dynamic wireless charging systems in order to provide adequate power stabilization and improve the efficiency of the transmission of power[15][16].

When all factors are considered, the literature analysis on electric car wireless charging provides enlightening information on the difficulty of electric car wireless charging infrastructure evaluation and construction. The findings associated with this research have the potential to be used in the development of a wireless charging network that is both reliable and effective for electric vehicles (EV) in the future. This could be accomplished through the examination of a variety of important factors, such as power transfer efficiency, interoperability, coil design, control systems, and thermal effects..

Compared the energy provider

Lithium batteries are presently being recognized as the most viable alternative for vehicle energy storage due to their practicality, efficiency, and expanding technological advancements. Because of their high energy density, lithium batteries are a great fit for electric vehicles (EVs) in a variety of settings, including urban commuting and longer-distance travel. Their extensive use is facilitated by the developed charging infrastructure and continuous battery technology developments.

Although solar energy and fuel cells provide alternatives, they come with drawbacks such limited efficiency and undeveloped infrastructure. The flexibility and ease of charging—whether via wireless technologies or conventional plug-in methods—complements the technology of lithium batteries. The practical realities of today's transportation scenario, however, indicate that lithium batteries are the favoured option for powering automobiles due to the current state of battery technology and its mix of efficiency, range, and infrastructural support.

2.4 Design

The design of electric vehicles, or EVs, has changed significantly in recent years due to a combination of consumer desires, environmental requirements, and technological improvements. The focus has shifted to the electric powertrain, which consists of the battery and electric motor. Its ongoing advancements are intended to increase range and enhance energy efficiency.

Design of rickshaw

The innovative and sustainable design of solar-powered tricycle rickshaws marks a notable divergence from conventional rickshaw architectures[2]. The design in Figure 9 use the steel body platform, plush seating, and generous space of this modern design meet modern demands. It uses a 48V, 500 RPM Brushless DC gear motor for electric propulsion, with four 12V, 20Ah rechargeable batteries. The frame modifications use CATIA V5 software for accuracy and technology[2].

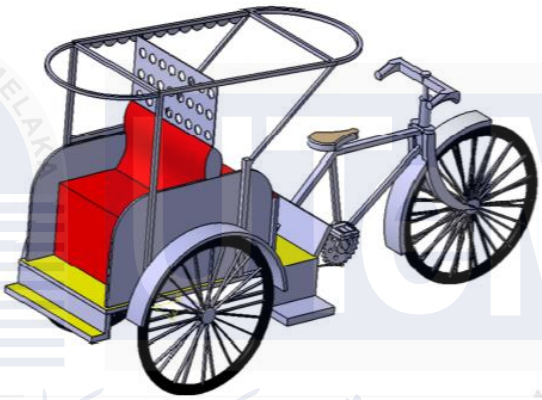


Figure 9 3D design of rickshaw[2]

The author in[4] discusses key design considerations for electric rickshaws, focusing on efficiency, performance, and sustainability. It emphasizes the use of a lightweight body with a box-style ladder structure, reducing weight and improving efficiency in Figure 10. The study emphasizes the use of galvanized iron for the ladder-type frame, ensuring structural integrity and weight management. The battery pack, featuring LiFePO4 batteries and an integrated BMS, is a key focus for improving battery lifespan and performance[4]. Next, the vehicle in[17] is equipped with a battery pack to store the electrical energy required to power the electric motor. The onboard solar charging system contributes to maintaining the battery pack's charge, thereby extending the vehicle's range and reducing its reliance on grid electricity in Figure 11.

Figure 10 body of rickshaw[4]

Figure 11 solar rickshaw[17]

This all-encompassing methodology for the design of electric rickshaws maximizes strength, efficiency, and sustainability, and reflects a holistic perspective on the ever-changing electric vehicle design environment.

Different design by vehicle

The design literature review places significant emphasis on a holistic approach towards solar-powered and electric vehicles, with a particular concentration on efficiency and sustainability. The review critically analyzes current technologies, developments, and contextual elements that have influenced the creation of these vehicles. The primary objective is to improve energy efficiency by optimizing the weight, materials, and aerodynamics of the vehicle[7], [9], [19].

The city car scale electric vehicle estimating weight and velocity, design takes into account forces such as air resistance, rolling resistance, and road inclination. The chassis is constructed from aluminum to ensure rigidity and light weight, whereas the body is optimized for energy efficiency and aerodynamics. The electric motor is replaced with a battery, and the design in Figure 12 is implemented using aluminum and carbon fiber[7].

Figure 12 Design of City Car Scale Evs[7]

The solar-powered vehicle design focuses on reducing carbon emissions and promoting sustainable personal mobility in urban environments[9]. It features a rechargeable battery pack, a lightweight motor, and two solar panels. The battery casing has four LA batteries and wiring for speed control. The rear wheel assembly aligns the wheel and motor on a straight line for perfect circular rotation. The design in Figure 13 also includes spokes of suitable length to maintain a constant distance between the motor and wheel. The goal is to reduce carbon emissions and promote sustainable mobility solutions[9].

Figure 13 Design of with Solar Powered[9]

Other paper such as [18] the vehicle design focuses on integrating solar and electrical power sources. A solar panel converts it into electrical energy, stored in a 48V battery. A solar charge controller regulates battery charging. The mechanical configuration includes a BLDC motor, DC-DC booster, and batteries for efficient power distribution. The design in Figure 14 also includes provisions for engine installation and driver comfort. The vehicle's chassis is made of iron channels, with a single-person seat and a braking system. The design emphasizes renewable energy integration, efficient power management, and environmental sustainability[18].

Figure 14 Series Hybrid Vehicles by using Solar and Batteries[18]

In summary, the design literature review underscores an all-encompassing and ecologically sustainable approach to automobiles powered by solar and electricity. This approach emphasizes the optimization of aerodynamics, materials, and weight in order to optimize energy efficiency. These designs exemplify a commitment to reducing carbon emissions, promoting the adoption of renewable energy sources, and devising urban transportation solutions through meticulous evaluation of materials, technologies, and overall system efficacy.

2.5 Performance of electric vehicles

The paper by Carlstedt and Asp [20] introduces a new framework for analyzing the performance of structural battery composites in electric vehicles. This framework estimates the electrical and mechanical properties of these composites, derived from material data and design considerations. By evaluating the impact of introducing structural batteries in existing electric vehicles like Tesla Model S and BMW i3, the study demonstrates potential weight savings and increased drive range.

The paper by Zhang et al. [21] introduces a simulation model to analyze how electric vehicles (EVs) perform economically and environmentally under different conditions. By considering factors like electricity sources, charging strategies, and pricing mechanisms, the study explores the potential benefits of EV adoption. The research emphasizes the importance of reducing battery costs to make EVs more competitive in the future and suggests that advancements in battery technology could lead to significant cost reductions.

2.6 Conclusion

In summary, the resurgence of trishaws as viable substitute modes of transportation for tourism destinations exemplifies a conscientious and environmentally conscious strategy towards urban exploration[22]. As part of Melaka's thriving tourism industry, trishaws are available for tourists to ride in. It is possible that tourists' experiences in Melaka may be enhanced if the city's rickshaw pullers were acknowledged as possible unpaid tour guides[22]. Furthermore, an article discusses the utilization of trishaws as tourist transportation in the city, emphasizing the necessity for governmental policies to facilitate the conversion of conventional vehicles into pedicabs intended for tourism objectives[23].

The most recent advancements in trishaw technology comprise several novel concepts that are designed to improve functionality, passenger convenience, and overall performance. One notable advancement involving trishaws includes the development of electric trishaws with torque sensors to assist the pullers and reduce the strain on their health[24]. Another advancement is the implementation of closed-loop speed control based on PID control for electric trishaws, which improves their performance and allows for automatic speed control[25]. These developments demonstrate the rapid progression of trishaw technology, encompassing a range of concerns including operator well-being, operational efficiency, and customer involvement.

Despite the burgeoning tourism sector, the rickshaw market persists in employing the traditional method, primarily represented by cycle rickshaws, where a cyclist pedals the vehicle. Referring to the objective, the development of electrical carriage in this project is to investigate and comprehensively evaluate all factors related to the design and operational aspects of the vehicle. The authors in [26] have tried to present an analysis of the performances of EVs. The authors have discussed various configurations and topologies of EVs. Furthermore, the authors have discussed how these technologies can be used based on the application in which they are adopted, also how these technologies are used to optimize the performance of these vehicles as compared to conventional vehicles. Due to superior fuel economy and vehicle performance, EVs will increase their popularity shortly. Research is going on for further improvement of the performance of the EV depending on the demand of the requirement.

CHAPTER 3

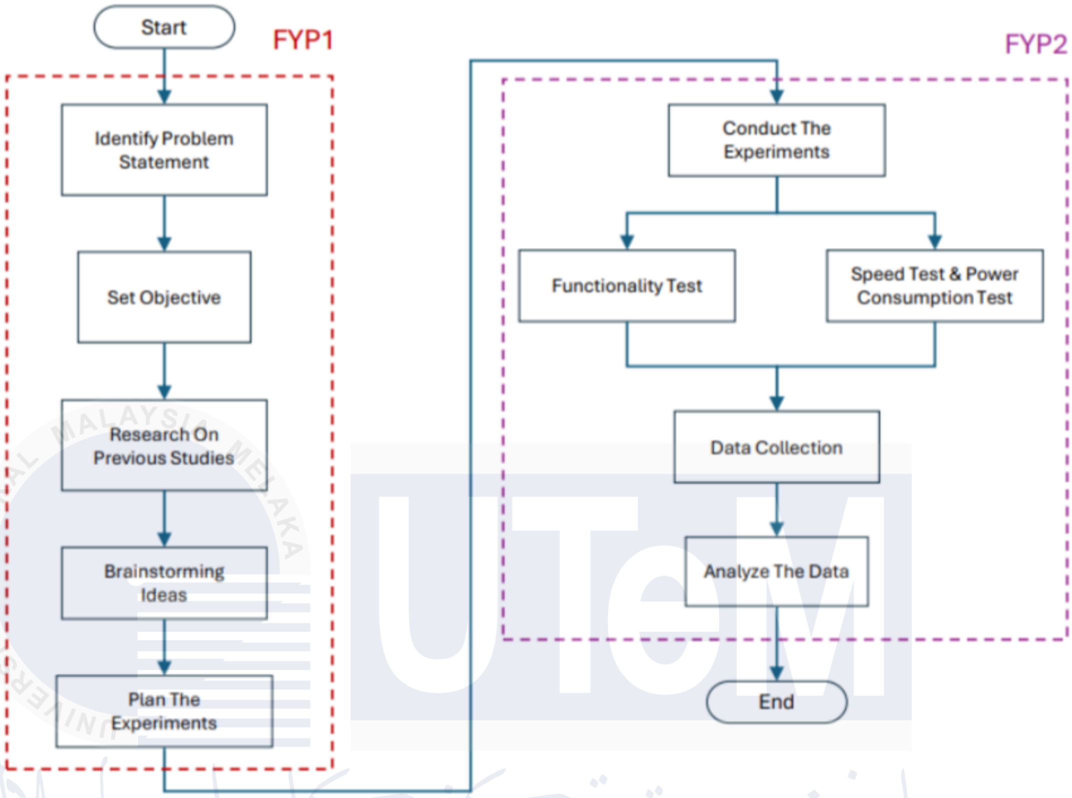
METHODOLOGY

3.1 Introduction

This chapter explains the method of electric vehicle design using Fusion 360 and Proteus software. Next, this analysis involves rigorous testing and validation to ensure its performance and safety align with industry standards. For assessing the responsiveness of the electric vehicle system, as well as the efficiency of the regenerative braking system, balance, and handling characteristics, controlled tests are carried out to evaluate the dynamic capabilities of the vehicle. Acceleration, speed, and energy consumption are all part of these capacities.

It is crucial to gather and analyze data to assess the design's effectiveness and determine its pros and cons. The end goal is to produce an electric vehicle that is reliable, powerful, and efficient enough to surpass industry standards for safety, performance, and efficiency. This method is employed to confirm the vehicle's viability and offer valuable suggestions for improving its design.

Flowchart


Start
FYP1
Identify Problem Statement
Set Objective
Research On Previous Studies
Brainstorming Ideas
Plan The Experiments
FYP2
Conduct The Experiments
Functionality Test
Speed Test & Power Consumption Test
Data Collection
Analyze The Data
End

3.2 Experiment Setup

For this chapter, explanation the experiment will be done. Determines the precision and dependability of the data produced, the experiment's design acts as the cornerstone that supports the whole research procedure. The present introduction offers a thorough synopsis of the experimental setup, techniques utilized, and the reasoning behind their choice.

3.2.1 Experiment 1 - Design an electrical carriage

Equipment :

1. Using fusion 360 software to design an eletrical carriage.

Procedure :

Fusion 360 software was used to create a conveyance for a four-wheel electric vehicle, combining advanced modeling with precision engineering. The software provides an interactive environment for creating a three-dimensional digital prototype, allowing for precise refinement and attention to detail. The parametric design capabilities enable real-time modifications to structural elements, shapes, and dimensions. The user-friendly interface allows architects to visualize the conveyance's structure and operation from multiple perspectives. The complex interconnection of circuits and components within electrical carriages significantly impacts the functionality and performance of electric vehicles. Software demonstrations help enhance understanding of these interconnections in a comprehensive manner.

3.2.2 Experiment 2 - To validate the operation of the proposed electrical system implemented to the electric carriage vehicle's system

Equipment :

1. Digital Multimeter (DMM)
2. Voltage calibrator
3. Clamp meter

Procedure :

Validating the operation of the voltage measurement apparatus through a series of procedures to ensure that the systems and components are functioning as intended is the focus of the test. A step-by-step guide follows:

1. System Overview:

Understand the overall design and components of the electric vehicle carriage. Identify key systems, including steering, braking, pedal, wheels and electrical systems in good condition.

2. Component Check:

Verify that all components, such as motors, batteries, controllers, and wiring, are installed correctly. Ensure that there are no loose connections or physical damage.

3. Power System Validation:

Verify that the voltage of the battery falls within the designated range. Verify that the charging infrastructure is operating as intended. Confirm that the power distribution system is operating properly.

4. Motor and Propulsion System:

Run the motor to ensure proper rotation and speed control. Validate the propulsion system's responsiveness to acceleration, speed and power.

5. Steering System:

Verify the steering system's response to steering inputs by subjecting it to testing.

6. Brake System:

Inspect and verify the braking system for responsiveness and effectiveness.

7. Collect the data

8. Safety precautions

Upon completion of measurement, power off the device and safely disconnect any connection established with the multimeter.

3.2.3 Experiment 3 - Analyze the performance of the real-world testing based on speed and acceleration of the carriage

Equipment :

1. Speedometers
2. Digital multimeter
3. Wireless speed sensor
4. Bracket L
5. PVC

Apparatus:

1. Starva Application
2. Google Earth Pro Cruise

Procedure of the pressure rate of the pedal determined by calculation as below:

Angle without pressure:

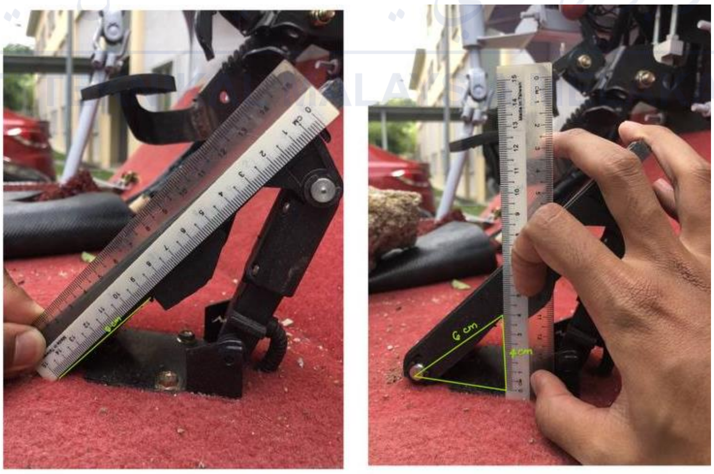


Figure 15 Trigonometry without pressure

$$\sin\theta = \frac{4}{6}$$

$$\theta = 41.81$$

$$\frac{Angle}{Max.angle} \times 100\%$$

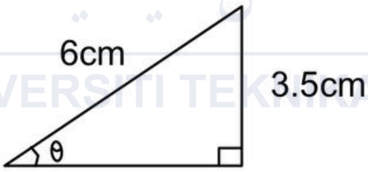
To ensure the reliability and consistency of data during the experiment, brackets (L-shaped) and PVC in Figure 16 were placed at the bottom of the pedal. This setup was used to prevent any movement and maintain stability throughout the experiment.

Figure 16 Brackets (L-shaped) and PVC

Speed 1: Approximately 30% for pressure rate of the pedal.

Figure 17 Trigonometry speed 1

Figure 18 Brackets (L-shaped) and PVC was used



$$\sin\theta = \frac{3.5}{6}$$
$$\theta = 35.69^\circ$$

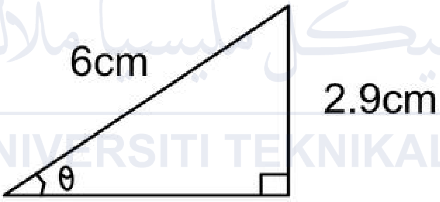
$$41.81^\circ - 35.68^\circ = 6.12^\circ$$

$$\frac{6.12}{19.27} \times 100\% = 31.76\%$$
$$\approx 30\%$$

Speed 2: Approximately 70% for pressure rate of the pedal.

Figure 19 Trigonometry speed 2

Figure 20 Brackets (L-shaped) was used



$$\sin\theta = \frac{2.9}{6}$$
$$\theta = 28.90°$$

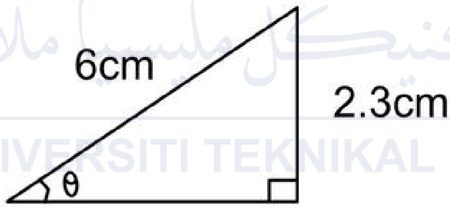
$$41.81° - 28.80° = 12.91°$$

$$\frac{12.91}{19.27} \times 100\% = 67\%$$
$$\approx 70\%$$

Speed 3: Approximately 100% for pressure rate of the pedal.

Figure 21 Trigonometry speed 3

Figure 22 without Brackets (L-shaped) and PVC for speed 3



$$\sin\theta = \frac{2.3}{6}$$
$$\theta = 22.54°$$

$$41.81° - 22.54° = 19.27°$$

$$\frac{19.27}{19.27} \times 100\% = 100\%$$
$$\approx 100\%$$

The flowchart of real-world testing based on speed and acceleration:

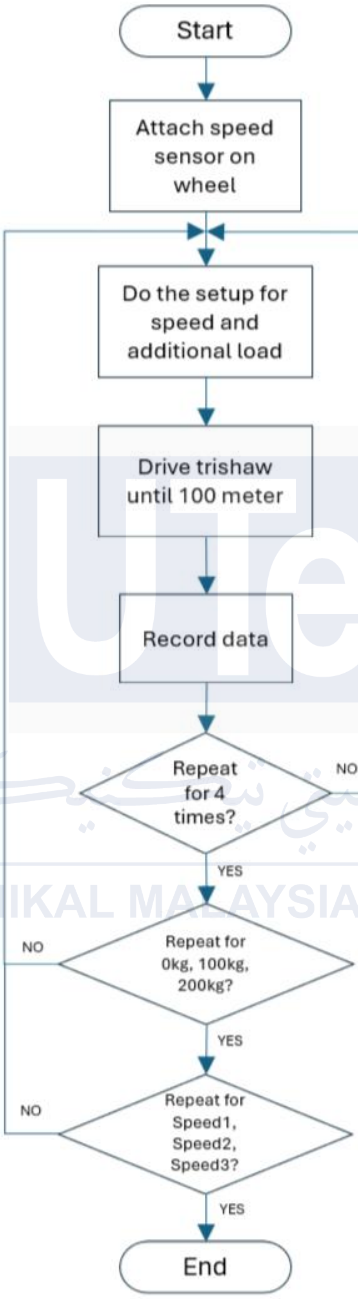


Figure 23 flowchart of real-world testing based on speed and acceleration

Procedures for measuring the carriage's speed test:

1. The carriage was loaded with the specified weights for each test condition: No load (0kg), 100kg and 200kg. Uses human mass as an experiment load.

2. The speed readings were recorded at 100-meter intervals during the test.

3. The first test with weight no load (0kg) commenced, and a pedal pressure rate proximity of 30% was applied to achieve speed 1.

4. To begin the experiment, calibrate a speedometer. For real-time data tracking, install the wireless speed sensor, and link it to the Strava app when initially after 5 meters to get a consistent speed.

5. After completing the first test run, the process was repeated three more times for weight 1 with speed 1.

6. The test continued with speeds 2 and 3 with the proximity pressure rate of the pedal of 70% and 100%.

7. The same procedure was followed for weights 100kg and 200kg and 4 test runs were conducted for each weight.

8. The average speed, the maximum speed and the total time taken for each test condition were recorded in the Strava application.

9. The data collected during the test was carefully documented.

3.2.4 Experiment 4 – Analyze the performance of the real-world testing based on power consumption of the carriage

Equipment :

1. Speedometers
2. Power meters
3. Application of Starva
4. Earth pro
5. Clampmeter
6. Multimeter

Appratus:

1. Starva Application
2. Google Earth Pro Cruise

Part 1: Three different road conditions (horizontal, uphill and downhill)

The flowchart of real-world testing based on power consumption Part 1:

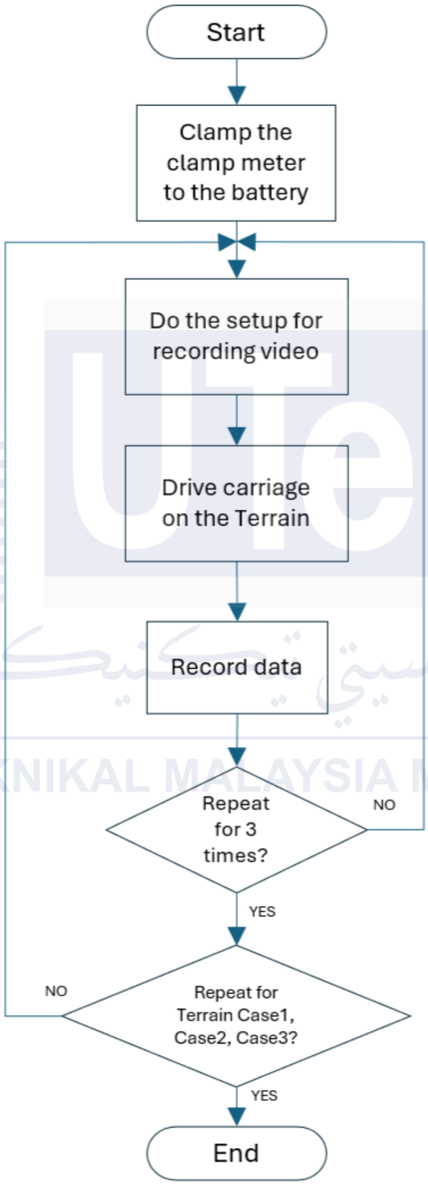


Figure 24 flowchart of real-world testing based on power consumption Part 1

Procedures:

1. Choose three different cases of terrain (horizontal, uphill, and downhill) with the same time constant for the power consumption tests. The starting point of the inclination is marked.

2. 30 meters distance is measured using measure tape from the beginning inclination and the ending point of measurement is marked as in the Figure 25.

Figure 25 measurement 30 meter using measure tape

3. The clamp meter is set to DC current measurement, and the wire that is connected to the positive terminal of battery is clamped. The setup to record the video of changing currents is set as Figure **26** below.

Figure 26 clamp meter for current set up

4. The video recorder starts to record as soon as the carriage starts to move and stops to record when reaches the ending point. Start recording using a speedometer connected to the Strava application after the initial 5 meters to ensure a consistent speed is achieved.

5. Apply 100% pressure on the pedal when starting to move up each terrain.

6. The data of the currents is documented from the recording video.

7. Step 4 to step 6 is repeated three times.

8. Step 7 also is repeated until all the different types of terrains such as horizontal terrain, uphill and downhill cases are done.

9. All the recorded data is re-organized and discussed

10. Consistency checks, conduct multiple current tests to ensure consistency and reliability of the recorded times.

Part 2: Three different angles of inclinations ($\theta = 2.25°, 3.15°, 6.10°$)

The flowchart of real-world testing based on power consumption Part 2:

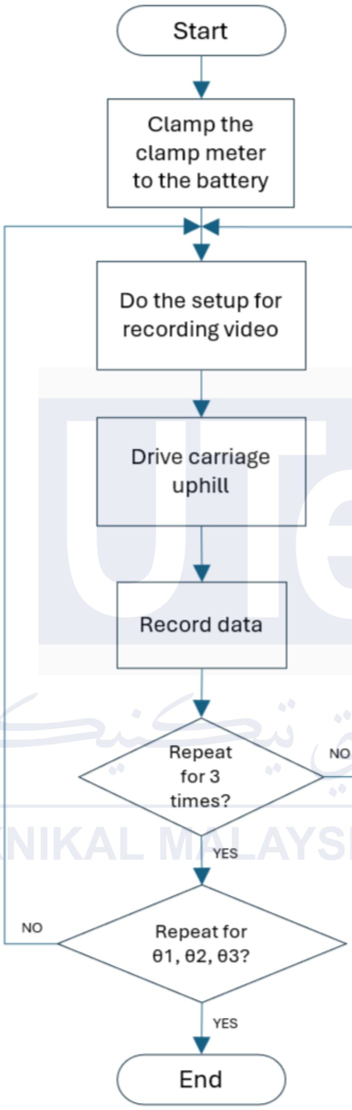


Figure 27 The flowchart of real-world testing based on power consumption Part 2

Procedure:

1. Choose three different hills with varying inclines for the power consumption tests. The angle of the terrain is determine by calculation below:

A. Angle of UTeM Archery Range

Figure 28 Earth pro at UTeM Archery Range

Elevation Gain = 7.88m

$$\sin\theta = \frac{7.88}{200}$$

$$= 2.25°$$

B. Angle of next to the Café FTKE building

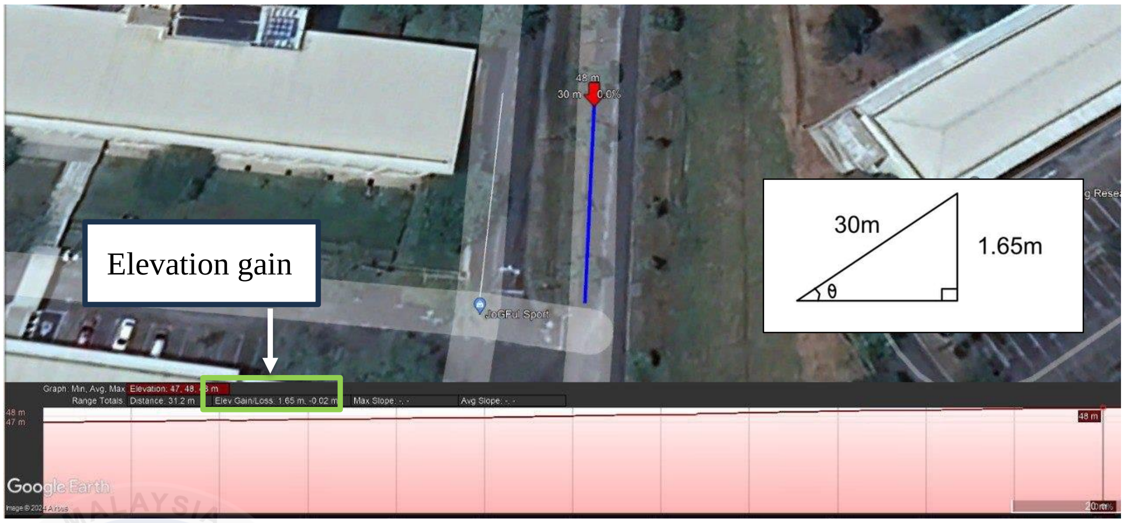


Figure 29 Earth pro at Café FTKE building

Elevation Gain =1.65m

$$\sin\theta = \frac{1.65}{30}$$

$$= 3.15°$$

C. Angle of next to block D building

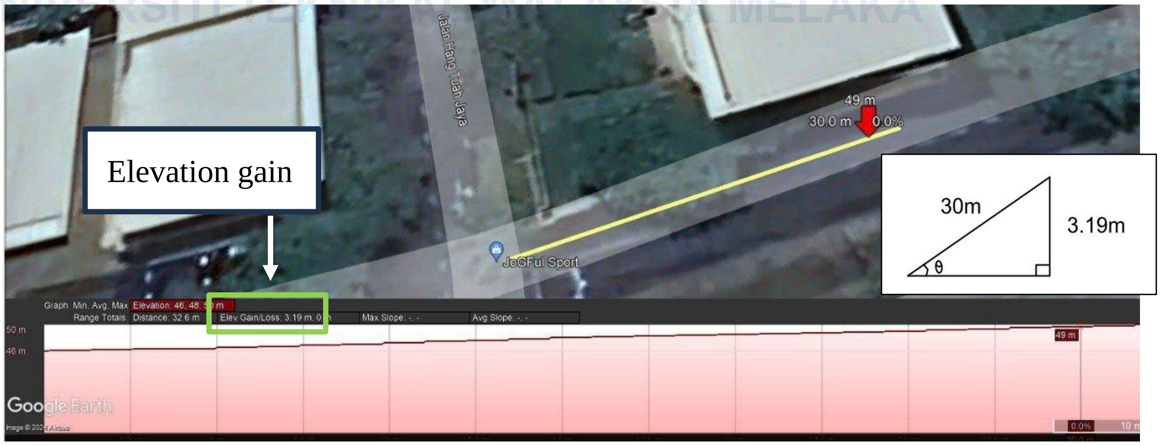


Figure 30 Earth pro at block D building of FTKE

Elevation Gain = 3.19m

$$\sin\theta = \frac{3.19}{30}$$

$$= 6.07°$$

1. Connect a multimeter in parallel with the battery to measure the voltage as Figure 31

Figure 31 connection multimeter for voltage

2. Use a camera to record the current and voltage readings during each test.

3. Start recording using a speedometer connected to the Strava application after the initial 5 meters to ensure a consistent speed is achieved.

4. Apply 100% pressure on the pedal when starting to move up each hill.

5. Take angle readings of each hill to document the incline.

6. The data will be taken at the same time constantly at each angle of the hills.

7. Perform the test repeatedly on each hill to ensure accuracy and consistency of the data.

8. Compare the current across the different hill angles based on the recorded current, voltage, and angle readings.

Part 3: Travel along the Route Road FTKE for voltage drop

The flowchart of real-world testing based on power consumption Part 3:

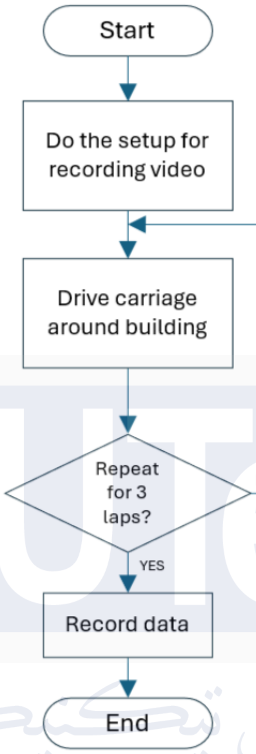


Figure 32 flowchart of real-world testing based on power consumption Part 3

Procedure:

1. Connect a multimeter in parallel with the battery to measure the voltage as Figure 31.

2. The initial voltage reading is recorded.

3. The GPS trackers and video recorder are started to record when the vehicle starts to move from the designed starting point.

4. The vehicle is driven for 5 consecutive laps, around the FTKE's building Figure 33

5. The GPS trackers and video recorder are stopped to record when the vehicle has fulfilled the 5 consecutive laps and reached the ending point.

6. Then, the voltages of the vehicle throughout the consecutive laps are documented with intervals of 15 seconds for a total of 11 minutes.

7. Distance measure for 5 laps, totaling 8.2km.

8. The voltage behavior is discussed.

Figure 33 Route Road at FTKE building

3.3 Reliability of data

The reliablity of data is paramount in ensuring the accuracy and validity of any experimental or analytical outcomes. Reliable data is characterized by its consistency and reproducibility under the same conditions, providing a solid foundation for making informed decisions and drawing meaningful conclussion. Ensuring data reliablity involves meticulous planning and execution of experiments, proper calibration of instruments and through documentation of procedures.

The all-encompassing strategy includes several parts and distinct functions inside the system, ensuring precision and uniformity in the outcomes. The initial experiment involved meticulous consideration of size, dimensions, and load-bearing capacity when creating the electric carriage's specifications using Fusion 360 software. A comprehensive validation method was carried out to ensure the proper and safe functioning of every component of the voltage measurement apparatus, including a voltage calibrator, digital multimeter, and other critical tools. Conducting many repetitions of each test aids in detecting any discrepancies or irregularities in the data, enabling a more thorough validation of the carriage's performance. The second experiment involved conducting real-world tests to validate the performance of acceleration, speed, and power consumption under different loads and topographical conditions. To guarantee the precision of the collected data, multiple tests were conducted and consistency checks were performed. To validate the efficiency and security of the carriage, its performance was assessed based on predetermined design standards and established industry benchmarks. The implementation of a systematic and thorough methodology in both studies guarantees a high level of dependability and precision in the evaluation of the electrical carriage's performance.

3.4 Ethic and safety

Analyzing electrical carriage involves a multifaceted exploration of ethical considerations spanning design, manufacturing, usage, and societal impact. Firstly, environmental sustainability is paramount, requiring scrutiny of mataerials, energy efficiency, and disposal practices. Safety standards must be rigorously upheld to protect drivers and passengers. Transparency and accountability are essential, ensuring stakeholders are informed and manufactures are held responsible for enthical breaches, fostering continuous improvement. Analyzing electrical carriage ethically necessiatates holistic examination to ensure they align with principles of fairness, safety, accessibility, economic prosperity, and social equality.

Analyzing the safety aspects of experimental electrical carriage involves several critical considerations. Firstly, the design and construction of these vehicles must undergo thorough scrutiny to ensure they meet stringent safety standards. Secondly, comprehensive testing protocols need to be stablished to evaluate the performance of experimental electrical carriage in various real-world scenarios. Additionally, experimental electrical carriage should be subjected to rigorous safety evaluations by regulatory authorities to verify compliance with applicable safety regulations and standards. Continuous monitoring and analysis of safety data from experimental trials are also essential to identify potential risks and implement necessary improvements to enhance the overall safety of electrical carriage.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter will include the thorough evaluation and inspection of an electrical carriage. A customized vehicle outfitted with an advanced electrical motorized infrastructure will be built first as part of the procedure. Extensive testing is conducted to validate the carriage's efficacy and ensure it functions according to the design criteria. A thorough study method considers aspects like energy consumption, acceleration, and speed to determine the carriage's efficiency.

4.2 Experiment Part 1 - Design carriage for electrical vehicle

Fusion 360 software was used to create a conveyance for an electric vehicle, combining advanced modeling with precision engineering. The software provides an interactive environment for creating a three-dimensional digital prototype, allowing for precise refinement and attention to detail. Various views, including side view in Figure 34, bottom view in Figure 35, and top views in Figure 36 will be generated to provide a holistic understanding of the carriage's structure.

The side view in Figure 34 provides significant value in terms of examining the carriage's lateral elements, including door positioning, seating configurations, and overall proportions. This perspective aids in assessing the visual coherence and ergonomic aspects of the design.

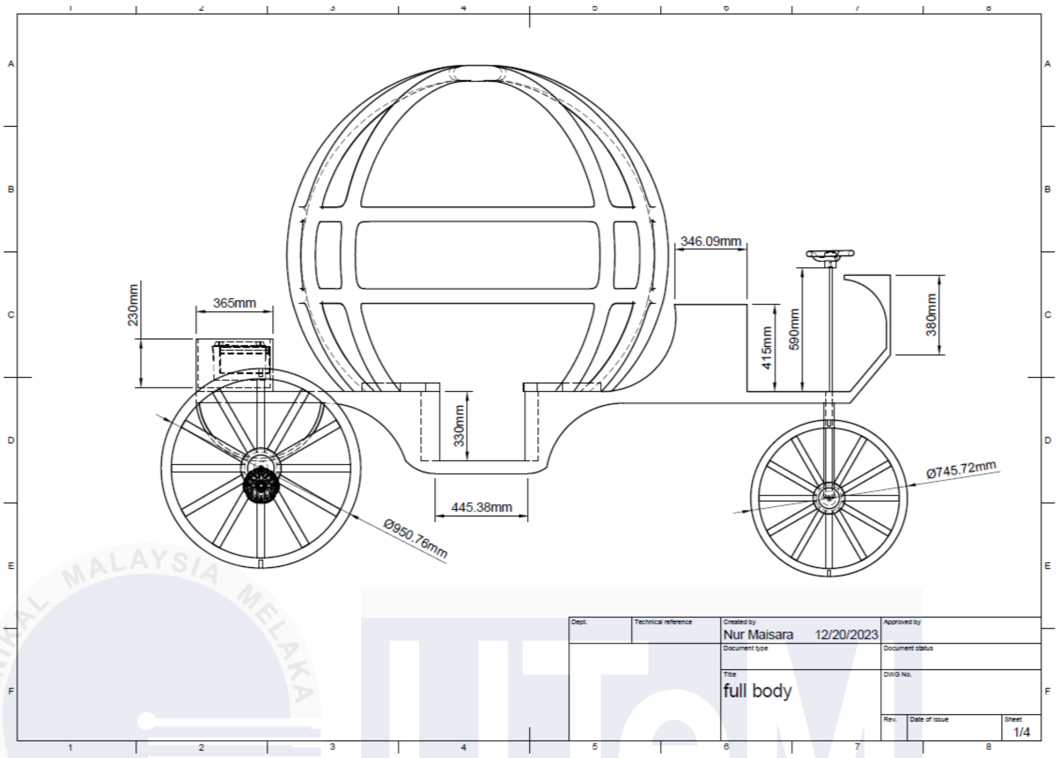


Figure 34 side view in fusion

Meanwhile, the bottom view in Figure 35 provides the opportunity for a comprehensive analysis of the undercarriage, which in turn provides information about the positioning of the wheels, stering, and seating. When it comes to guaranteeing the carriage's stability and overall structural integrity, this angle plays its most important role.

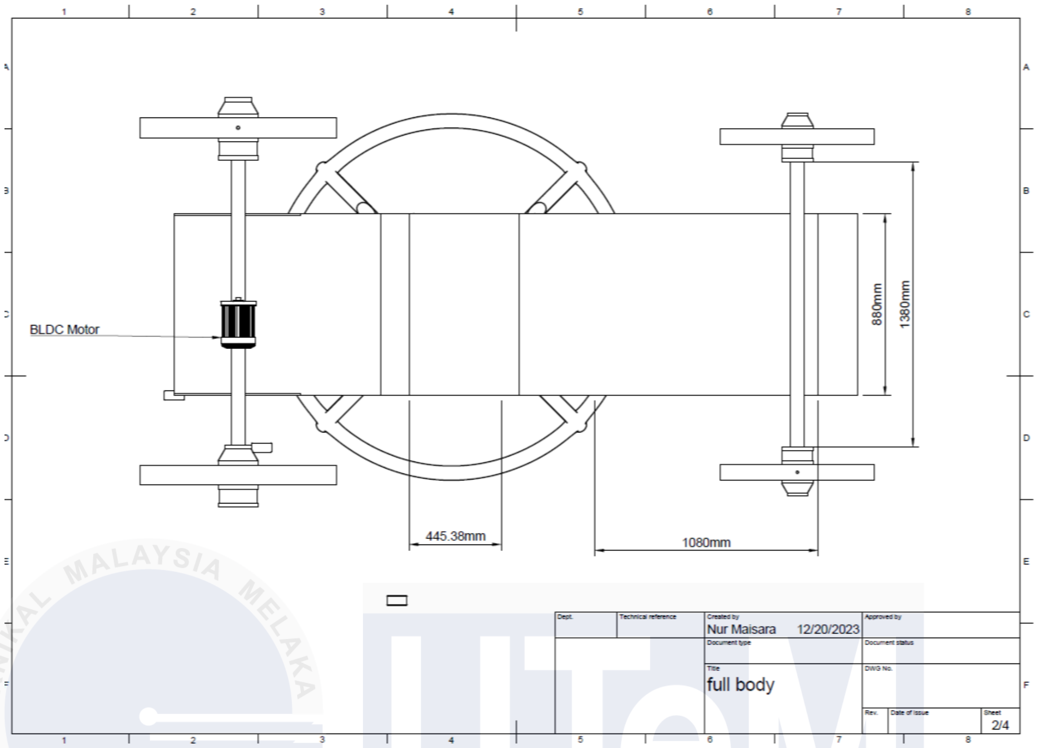


Figure 35 Bottom view in fusion

Lastly, the top view in Figure 36 offers a comprehensive overview of the spatial arrangement of internal components, facilitating the optimization of layout and dimensions.

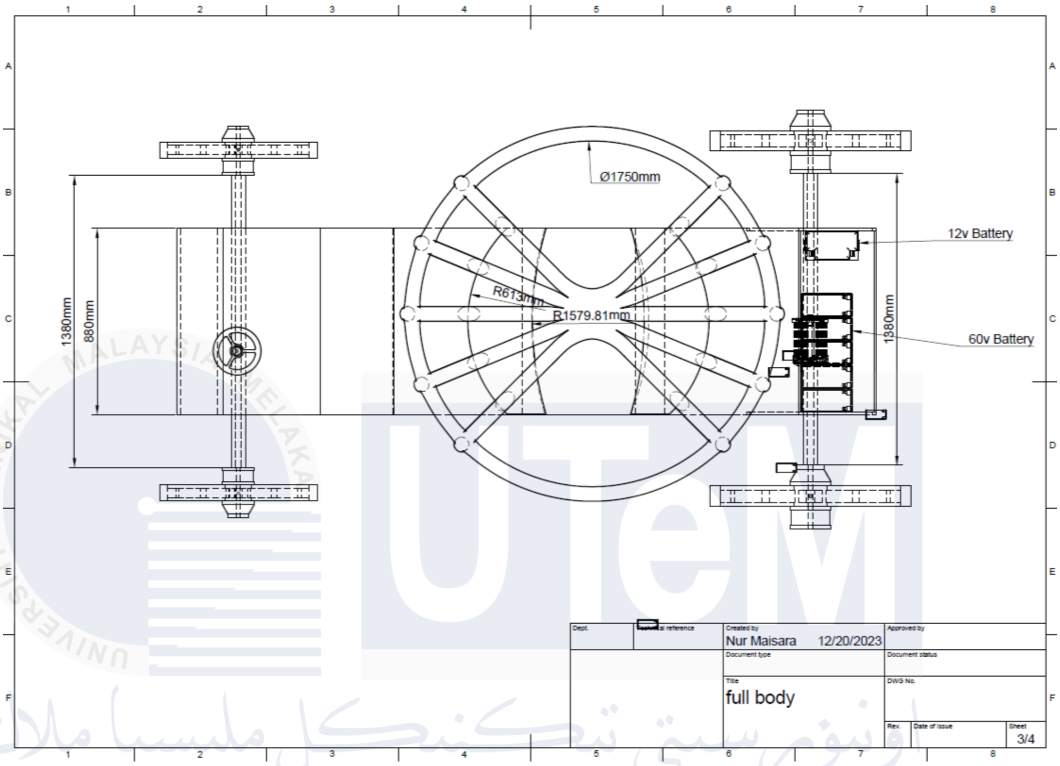


Figure 36 Top view in fusion

Together, these views play a synergistic role in guiding the design process, ensuring a holistic understanding of the rickshaw carriage's structure, and ultimately contributing to the creation of a well-balanced and functional product.

The descriptions of various components that are used for modelling and designing the experimental setup are as follows:

1. The first one is the 5 rechargeable batteries with a series connection with a total of voltage 60v connected with a stream brushless (BLDC) controller. The smart (BLDC) controller with a range voltage of around 48V-60V is connected to the high-capacity brushless BLDC electric vehicle motor with a power of 2.5kW and voltage of 60V. The smart BLDC controller can frequently give approximately 90±2A of current supply compared to other motors; hence a motor controller is necessary. The high-capacity brushless BLDC electric vehicle motor is well-known as a brushless DC motor that does not utilize brushes and performs better than the brushed one. The connection of wiring like in Figure 37.

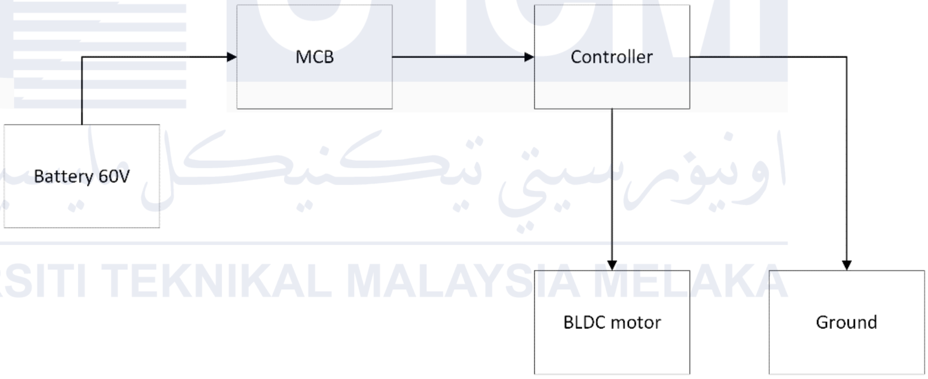


Figure 37 circuit connection with controller and BLDC motor

2. Next, connecting RGB (Red, Green, Blue) LEDs in a carriage involves wiring each LED to a power source and a stream (BLDC) controller for color control. Here's a basic guide on how to wire and connect RGB LEDs with constant current LED in a carriage in Figure 38:

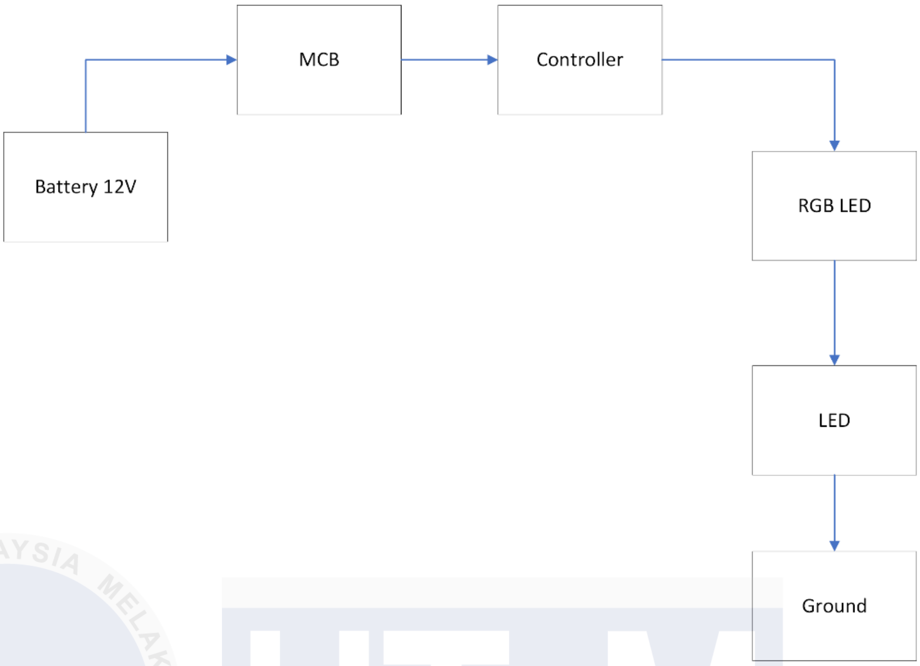


Figure 38 circuit connection RGB with Constant Current LED

3. The accessories like reverse camera, android player and speaker connect to a power source and a stream (BLDC) controller in a carriage like in Figure 39.

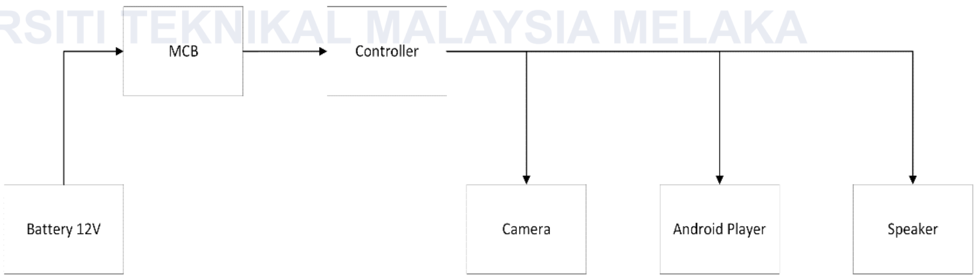


Figure 39 circuit connection with accessories

4.3 Experiment Part 2 - To validate the operation of the proposed electrical system implemented to the electric carriage vehicle's system

The operation of the system for the electric vehicle carriage has been thoroughly validated and proven to be functioning effectively through a comprehensive measurement of voltages at critical points within the electrical architecture. Voltage measurements were conducted at key components, including the battery, motor, controller, and other accessories etc.

Lithium battery power supply 12V and 60V

The battery in Figure 40 and Figure 41 battery power supply 12v voltage was confirmed to be within the specified operating range, exhibiting stability during normal operation. The power distribution system demonstrated efficient voltage distribution with minimal voltage drop across contactors, fuses, and junction points.

Figure 40 Lithium battery power supply connected with 5 in series with total voltage 60v

Figure 41 battery power supply 12v

The specifications of the Lithium battery power supply 12V and 60V used in the experimental setup are presented in the Table 2:

Table 2 The specifications of the Lead-acid Battery Power Supply

Features	12V Battery	Connected with 5 in series 60V Battery
Nominal Voltage	12V	60V
The actual voltage	13.2V	68V
Rechargeable	Yes	Yes

Smart brushless controller

The smart BLDC controller in Figure 42, a pivotal component in the vehicle's propulsion system, underwent rigorous testing. Voltage measurements at the input and output terminals of the controller verified that it efficiently managed and distributed power to the BLDC motors, supporting various driving scenarios with consistent performance.

Figure 42 Smart brushless controller

The specifications of the Stream Brushless Controller used in the experimental setup are presented in Table 3:

Table 3 Specification of Smart Brushless Controller

Features	Specification
Item type	Smart Dual Mode Electric Vehicle Controller
Material	Aluminum
Rated Power	800W
Rated Voltage	48V-60V
Limit Current	90±2A

High-capacity brushless BLDC electric vehicle motor

For the BLDC (Brushless Direct Current) motors in Figure 43, precise voltage measurements were taken at their terminals, ensuring that the motors received the requisite voltages for seamless and controlled propulsion.

Figure 43 High-capacity brushless BLDC electric vehicle motor

The specifications of the High-capacity brushless BLDC electric vehicle motor used in the experimental setup are presented in the Table 4:

Table 4 High-capacity brushless BLDC electric vehicle motor

Features	Specification
Power	2.5kW
Voltage	60V
Current	52A
Rated speed	470 r/min
Weight	18.8kg

LED

The RGB LED in Figure 44 and Constant Current LED in Figure 45 exhibited the desired illumination without voltage-related issues.

Figure 44 RGB LED

Figure 45 Constant Current LED

The specifications of the LED used in the experimental setup are presented in the Table 5:

Table 5 Specifications of the LED

Product name	RGB LED	Constant Current LED
Power	60W	6.2W
Input voltage	12V	24V
The Actual voltage	12.3V	9.5V
Emitting Color	RGB	2200K-6500K
Ingress Protection Rating (IP)	IP65	IP20/IP67

Reverse Camera

The camera reverse in Figure 46 displayed clear and reliable visuals.

Figure 46 Reverse Camera

The specifications of the Reverse Camera used in the experimental setup are presented in the Table 6:

Table 6 Specifications of the Reverse Camera

Features	Specifications
Nominal voltage	12V
The Actual voltage	12V
Effective pixels	648 (H) x 448(V)
Operating Temperature	20º - 70º
View Angle	Diagonal viewing angle 170-degree, horizontal viewing angle 110 degree

Andriod Player

The Android in Figure 47 player operated seamlessly.

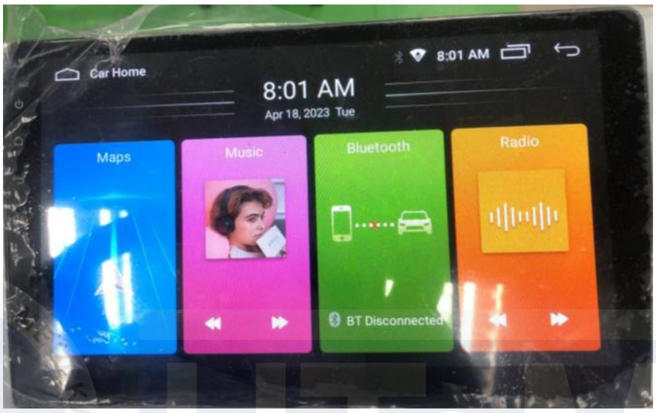


Figure 47 Android Player

The specifications of the speaker used in the experimental setup are presented in the Table 7:

Table 7 The specifications of the Android player

Features	Specification
Rated Voltage	12V
The Actual voltage	11.56V
Output Power	180W

Speaker

The speaker in Figure 48 delivered with good sound.

Figure 48 Speaker

The specifications of the speaker used in the experimental setup are presented in the Table 8:

Table 8 The specifications of the Speaker

Features	Specifications
Rated power	20W
Input Voltage	100V
The Actual voltage	0.5V with volume sound 8db
Sensitivity	92dB

In this experiment aimed at assessing the electrical performance of a carriage, a systematic analysis of voltage across every operational component is conducted. Precision multimeters are strategically employed to measure voltage levels at key points within the carriage's electrical system, including the battery, motor, lighting systems, and other critical components. Voltage readings in Table 9 are recorded during various operational states, providing a dynamic snapshot of the electrical behavior under different conditions. The objective is to evaluate the stability and consistency of voltage supply to each component, detecting any irregularities or fluctuations that could impact performance.

Table 9 Parameter reading

Components	Parameter Reading
60V Battery	60v
12V Battery	12v
RGB Led	2v-3.3v
Single-color Led	1.8v-3.6v
Android player	11.56watt
Reverse Camera	1.6watt
Speaker	4ohm

4.4 Experiment Part 3 - Analyze the performance of the carriage

The Figure 49 presents the relationship between the average speed and the load carried by an electrical carriage. It displays 3 different speed profiles (Speed 1, Speed 2, Speed 3) corresponding to different load condition: 0kg, 100kg and 200kg.

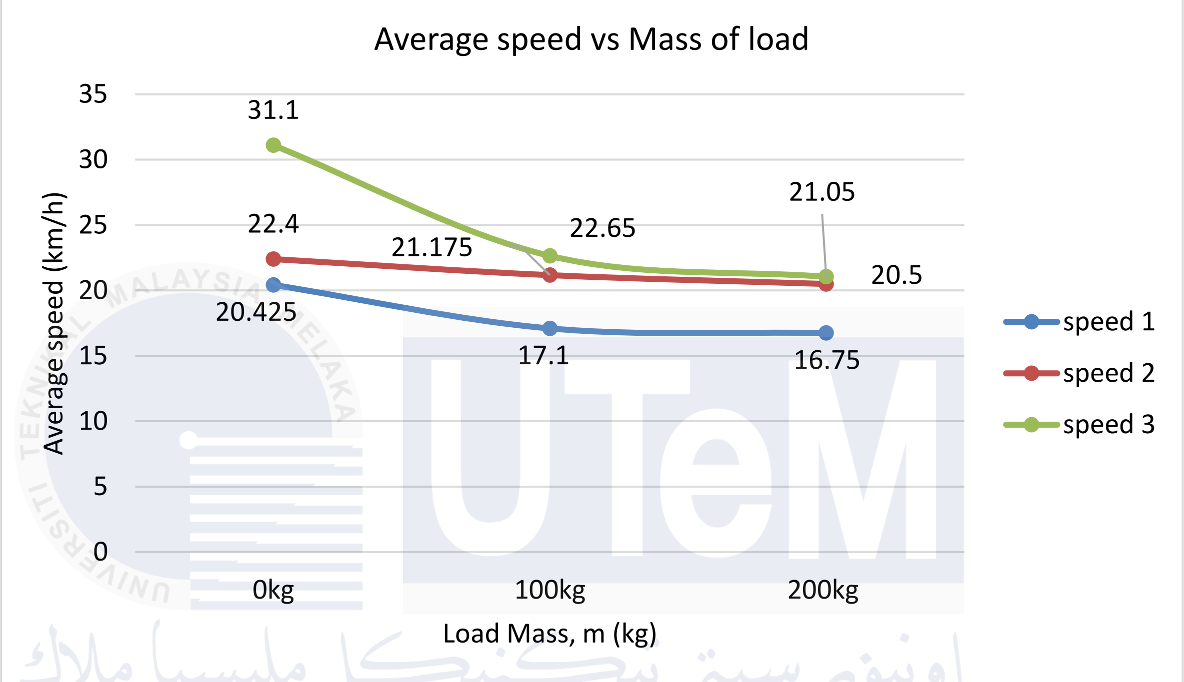


Figure 49 Average speed vs load

At the 0kg load condition, the average speed for all three profiles is relatively high, with Speed 3 being the highest at 31.1km/h, following Speed 2 at 22.4 km/h, and Speed 1 at 20.425km/h. This is expected because without any additional load, the electrical carriage can accelerate and reach higher speeds more easily, as the motor's force is applied to a relatively small mass.

At load 100kg, the average speeds across all 3 profiles decrease. Speed 1 drops to 17.1km/h, speed 2 decreases to 21.175km/h, and speed 3 falls to 22.65km/h. With a heavier load, the same amount of force from the motor results in lower acceleration and consequently, lower average speed.

When the load is further increased to 200kg, the average speeds continue to diminish. Speed 1 drops to 16.75km/h, Speed 2 decreases to 20.5km/h and Speed 3 reaches 21.05km/h. The mass requires more force to accelerate and maintain the same speed.

It is noticed that the curve of the average speed of Speed 2 and Speed 3 are nearly touching each other. This can be explained by the efficiency of DC motors. The efficiency of DC motors plays a significant role in their performance under varying loads. DC motors operate within certain efficiency ranges, and when they are subjected to increasing loads, their efficiency affects how speed changes. If both Speed 2 and Speed 3 settings fall within the high-efficiency range of the motor's operation, the motors may exhibit similar speed behaviors under different loads. This is because, within this optimal range, the motors can handle additional loads with minimal speed reduction, resulting in closely matched average speeds.

Next, the torque-speed relationship of a DC motor is typically linear. This means that as the load increases, the speed decreases proportionally if the voltage remains constant. If the voltages set for Speed 2 and Speed 3 produce similar torque outputs for the given loads, their speeds will be close. If Speed 2 and Speed 3 are set near these saturation points, the performance difference can be minimal, leading to nearly identical average speeds under different loads.

The data demonstrates that as the load increases, the vehicle experiences a reduced ability to accelerate and maintain higher speeds. For sharp decrease highlights the limitations in the motor's ability to maintain high speeds when subjected to greater mass, likely due to increased demands for torque and power that the motor cannot consistently meet. Furthermore, the efficiency of the battery and its ability to supply steady power output also plays a critical role, leading to quicker depletion and reduced performance.

The Figure 50 presents the relationship between acceleration $(\frac{m}{s^2})$ and load (kg) for 3 different profiles, labeled as Speed1, Speed2, and Speed 3. It illustrates how increasing the load affects the acceleration capability of an electrical carriage.

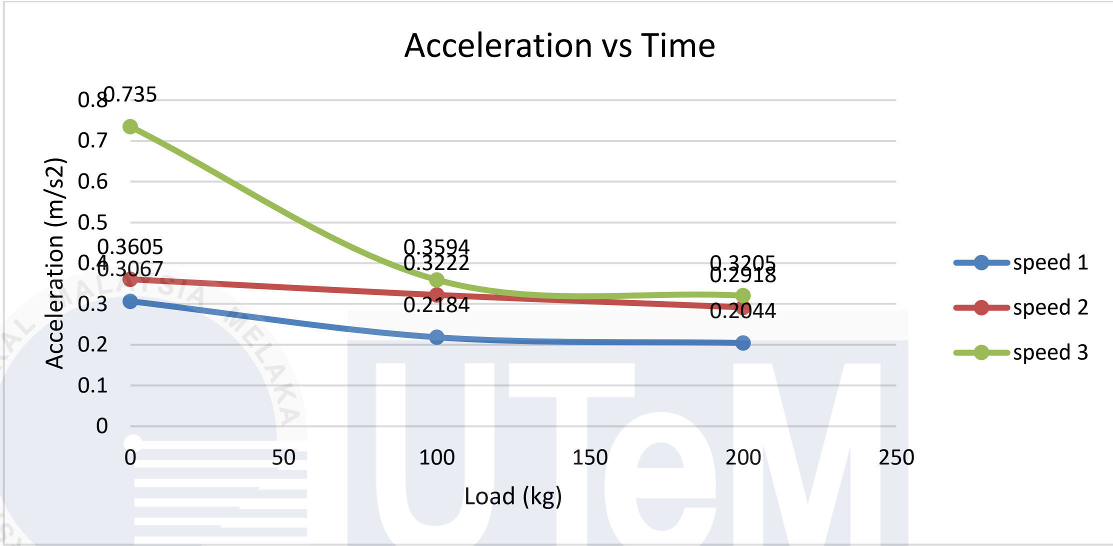


Figure 50 Acceleration vs time

At Speed 1, the inital acceleration start at 0.3067 $(\frac{m}{s^2})$ with no load. As load increses to 50kg, the acceleration decreses to 0.2184 $\left(\frac{m}{s^2}\right)$ and further drops to 0.2044 $(\frac{m}{s^2})$ at 100kg. This gradual decline indicates that Speed 1 is relatively stable but provides the lowest acceleration among the 3 speeds tested.

For Speed 2, initail acceleration is slightly higher at 0.3605 $(\frac{m}{s^2})$ withhout any load. When the load reaches 50kg, the acceleration decreses marginally to 0.3222 $(\frac{m}{s^2})$ and maintains a nearly consistent level at 100kg with an acceleration of 0.3205 $(\frac{m}{s^2})$. Speed 2 exhibits a moderate and stable performance under varying loads, indicating it may offer a balanced approach between speed and load-handling capacity.

Speed 3 shows the highest initial acceleration of 0.735 $(\frac{m}{s^2})$ at 0kg load, but it also experiences the steepest decline as the load increases. At 50kg, the acceleration significantly drops to 0.3594 $(\frac{m}{s^2})$ and further stabilizes at 0.2918 $(\frac{m}{s^2})$ at 100kg. This indicates that while Speed 3 provides the highesr initial acceleration, it is highly sensitive to increased loads, resulting ina substantial reduction in performance.

As the load on an electrical carriage increases, it generally takes more force to change speed, which can result in lower acceleration. This is because the electrical carriage's motor has to work harder to overcome the increased inertia due to the added load.

4.5 Experiment 4 – Analyze the performance power consumption of the carriage

Part 1: 3 different road conditions (straight road, uphill and downhill)

The Figure 51 provided illustrates the current (I) in Ampere (A) over time (t) in second (s) for 3 distinct cases: Case 1 (straight road), Case 2 (uphill) and Case 3 (downhill).

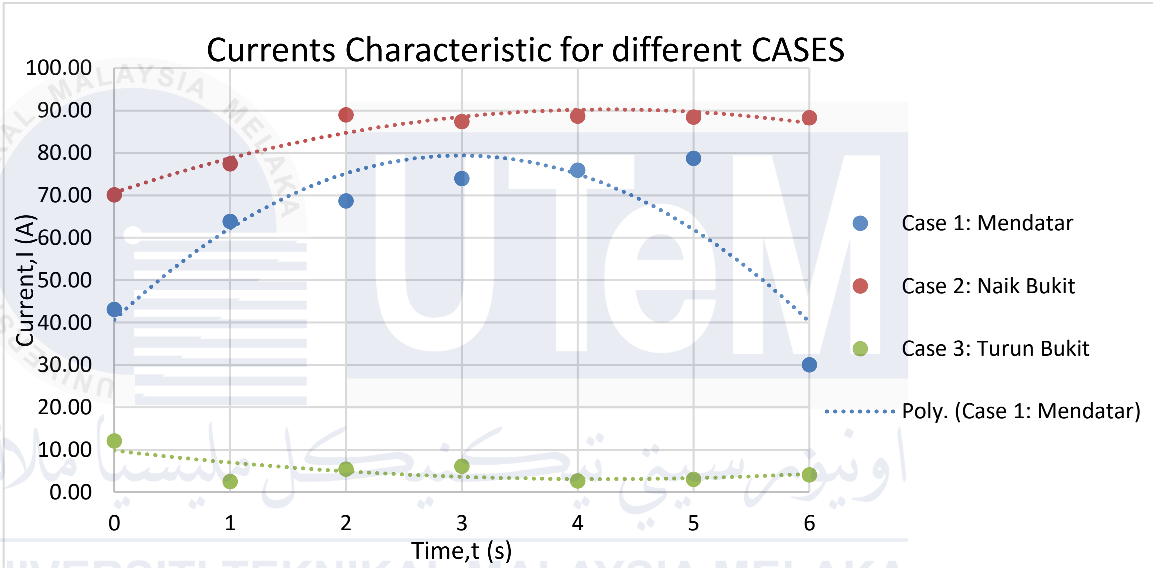


Figure 51 Current vs time for different cases

In Case 1 (straight road), depicted by blue dots, the initial current starts at approximately 10A. The current shows a steady increase, peaking at around 3 seconds with a value close to 70A. Following this peak, the current then decreases because of brake, returning to around 10A by the 6 seconds.

In Case 2 (uphill), represented by red dots, the initial current starts significantly higher, around 70A. The current rises sharply, reaching a peak around 5 seconds at approximately 90A before experiencing a slight decline. The reading of the current supplied to the output battery will increase, because the motor is working hard. Gravitational force works against the direction of motion of the motor, thus requiring more energy to overcome the force.

In contrast, Case 3 (downhill), shown by green dots, start with the lowest initial current, around 5A. Throughout the period, the current remains relatively low, exhibiting minor fluctuations but no significant increases or decreases. The reading of the current supplied to the output battery is low because the motor doesn't need to work as hard anymore.

Overall, these analyses provide insight into the behaviour of the system under different conditions. Understanding these patterns can aid optimizing performance, ensuring that the system operates efficiently under different conditions.

Part 2: 3 different angles of hills ($\theta = 2.25°, 3.15°, 6.10°$)

The Figure 52 illustrates the relationship between average current (Ampere) and the angle of the hills (in degree). The x-axis represents the angles of the hills, while the y-axis represents the average current (Ampere). The graph shows the data point, each corresponding to a specific angle and its associated current, along with a fitted linear regression line that models the relationship between these two variables. The equation linear regression line is

$$Linear\ of\ current\ average = 0.9792x + 69.964.$$

The study examined 3 different angles of inclination to assess the current draw under varying conditions. For Hill 1, at an angle of 2.25°, the average current recorded was 70.68A. For Hill 2, at an angle of 3.15°, the average current recorded was 72.44A. Finally, for Hill 3, at an angle of 6.10°, the average current recorded was 72.64A. These measurements provide a comprehensive understanding of the current demands at different angles, highlighting the variations in electrical load as the angle of inclination increases.

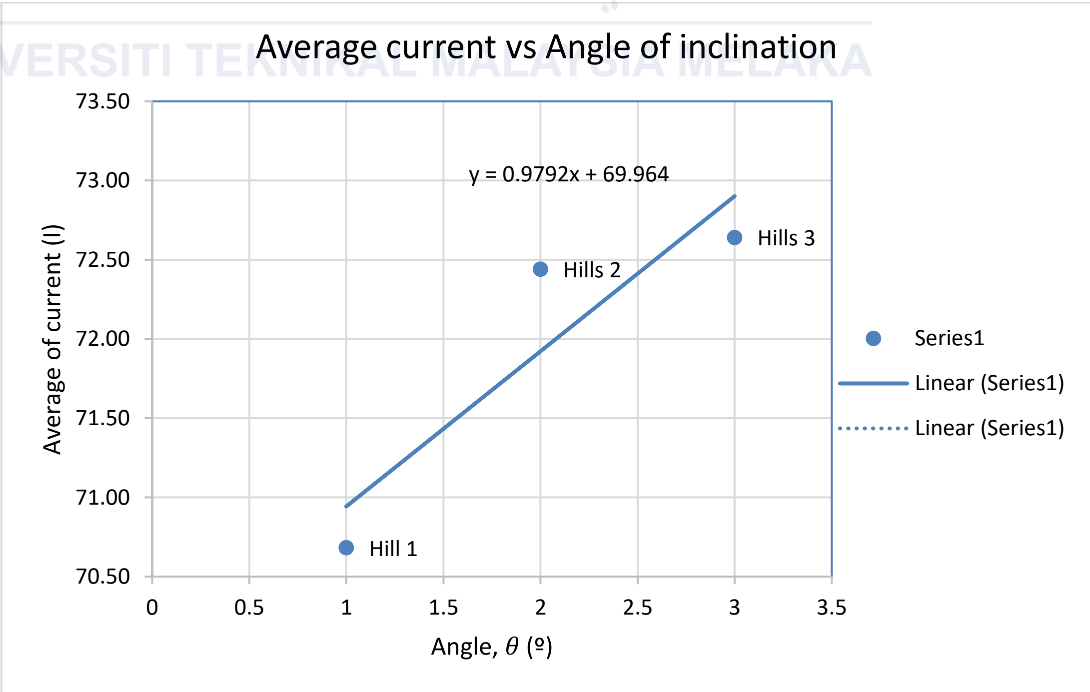


Figure 52 Average current vs Angle of inclination

As the incline becomes steeper, the electrical carriage requires more current to maintain its operation. The relationship between current and angle of hills is directly proportional, as evidenced by the positive correlation depicted in the graph. The angle of hills increases, the average current needed to move the carriage also increases.

The consistent linear trend also indicates that the motor and the system it drives have a predictable response to increased load due to steeper inclines. The efficiency of the motor, while important, appears to be stable across the range of inclinations, leading to a proportional increase in current draw rather than any erratic or nonlinear behavior. This suggests that the motor operates within an efficient range for the inclinations tested, maintaining consistent performance.

A Miniature Circuit Breaker (MCB) with a current limit of 100A, if the current exceeds this threshold, the MCB will trip to interrupt the circuit. This mechanism is designed to protect electrical circuits from damage caused by overcurrent or short circuits. When the current surpasses the 100A limit, the MCB automatically disconnects the electrical flow, thereby preventing potential hazards such as overheating, fire, or damage to electrical components. This protective feature ensures the safety and reliability of the electrical system. It is predicted that, under normal conditions, the carriage can operate up to an inclination angle of $30.67°$ with the increment of 0.9792 A/θ. However, due to the overload imposed by the structural design, achieving this maximum angle value is deemed impractical.

The Figure 53 ‘Power consumption vs Angle’ provides a detailed illustration of the relationship between power consumption, measures in watts, and the angle of inclination, measured in degree, across three different hills. The data points for each hill show a clear trend of increasing power consumption as the angle of the hill becomes steeper.

At the angle of 2.25° for Hill 1, the power consumption is recorded at 4567.71 watts. As the angle increases to 3.15° for Hill 2, the power consumption rises to 4608.71 watts.

Next, at an angle of 6.10° for Hill 3, the power consumption reaches 4762.65 watts. The linear regression equation provided on the graph:

$$Linear\ of\ power\ consumption = 51.019x + 4450.8$$

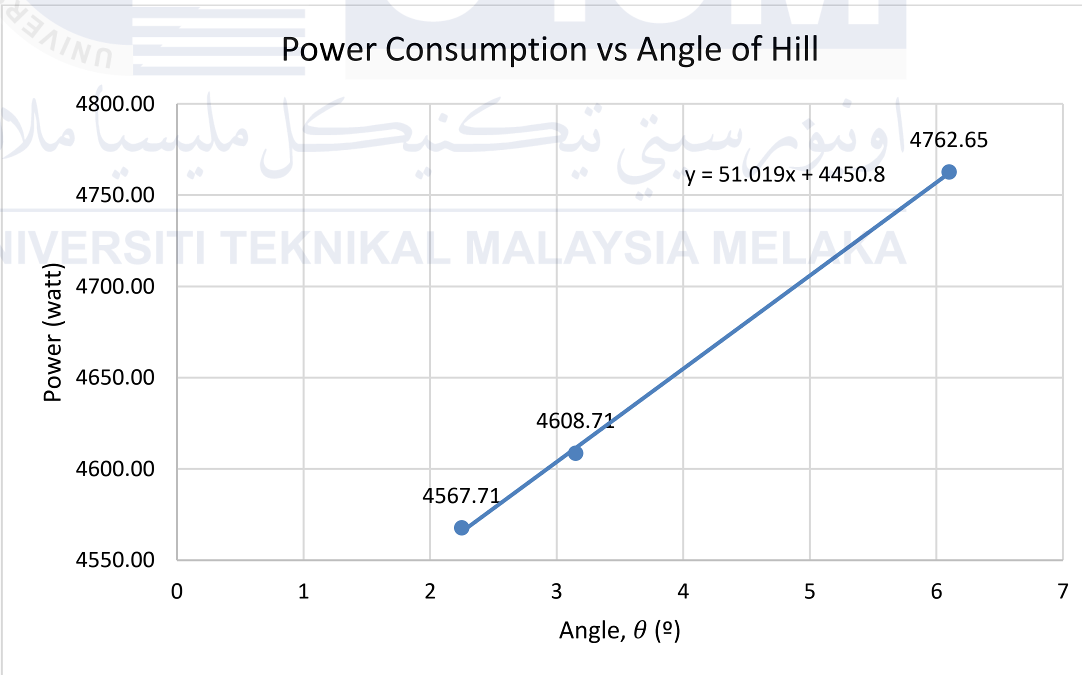


Figure 53 power consumption vs Angle

This analysis underscores the importance of dynamics for optimizing energy usage in vehicles. Efficient power management system must account for the increased energy demand associated with steeper inclines to ensure optimal performance and energy efficiency.

Part 3: Test drive a carriage along the Route Road FTKE for voltage drop

The Figure 54 presents a plot of voltage against time, displaying an oscillating pattern of voltage values over the given time period. This experiment to measurement scenario involving a carriage traveling along a route called Route Road FTKE. The objective of this experiment was to take voltage drop readings while the carriage was in motion, covering a total distance of 8.2km with time taken 11 minutes (660 seconds).

Initially, the battery starts at approximately 65.0v, but within the first 200 seconds, it experiences significant voltage drops, reaching as low as 59.5v. These early fluctuations likely result from varying power demands on the carriage. The linear trend line, with a negative slope of -0.0028, indicates a gradual average decline of 0.0028v per second.

From 200 to 400 seconds (2 minutes 33 seconds to 6 minutes 67 seconds), the voltage oscillates between 59.0v and 62.0, suggesting cyclical load patterns or brief recovery periods. By 500 seconds (8 minutes 33 seconds), the voltage consistently dips to around 59.0v, showing repeated significant demand on the battery. Towards the end of the 660 seconds (11 minutes), the voltage stabilizes somewhat at around 60.5v, but the overall trend from the initial voltage reveals a substantial decline. This steady drop highlights the battery's discharge under load, nearing the critical 59.0v threshold triggers an automatic shutdown to prevent damage.

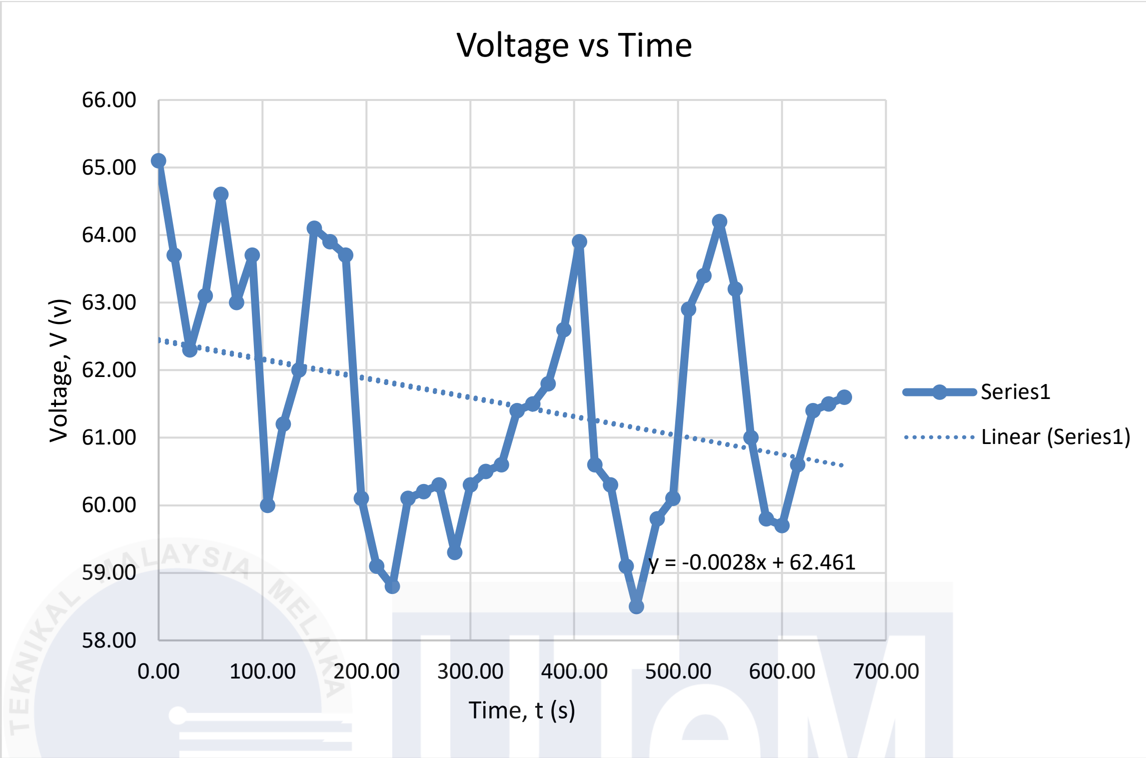


Figure 54 Voltage vs Time

The graph reveals a gradual decrease in the overall voltage levels over time, as indicated by the negative slope of the linear approximation line. This downward trend in voltage could be a consequence of various phenomena, including battery discharge, power consumption, or voltage drops caused by resistive losses within the electrical system powering the carriage.

When an electrical carriage experiences a low battery condition, its performance and overall electrical system are significantly impacted due to the inherent characteristics of battery discharge. As the battery discharges, its voltage decreases, which is a fundamental aspect of battery chemistry.

In this specific case, it is predicted that the electrical carriage can operate for up to 2.5 hours based on the linear negative slope of the discharge equation:

$$Linear\ of\ negative\ slope = -0.0028x + 62.461$$

The minimum voltage required to keep the system operational before triggering an automatic shutdown is 59v. Understanding these dynamics is crucial for maintaining the efficiency and longevity of electrical carriage, ensuring they remain a reliable mode of transportation.

By taking the consideration of the nominal operating voltage of DC Motor, which is 60V, as the cut-off voltage, it can be predicted that the electrical trishaw is able to operate up until 14 minutes 65 seconds with the rate of voltage deplete of 0.0028 v/s when driving around FTKE’s building consecutive laps without stopping.

4.6 Discussion

After conducting thorough tests on the validation of the proposed electrical system implemented in the electric carriage vehicle Figure 55, it is apparent that the electrical carriage is functioning normally and without any issues. Conducting a thorough examination and testing of critical elements including the battery, motor, controller, and additional accessories, ensures that the integrated system performs effectively as intended.

Figure 55 Electrical carriage

With precise voltage measurements conducted at critical points within the electrical motorized, any irregularities or fluctuations that could potentially impact performance are identified and addressed. Consequently, the electric carriage Figure 56 exhibits peak performance, exhibiting its capability to maneuver through a variety of operational situations, maintain its stability, and provide consistent results.

Figure 56 from front view

4.7 Conclusion

The experiment evaluated the electrical performance of an electric carriage using Fusion 360 software and a systematic design process. Images were collected from various angles to understand the carriage's architecture. A series of stability and consistency tests were conducted on the voltage measuring operation system to guarantee that its functional capabilities correspond to the design specifications.

Based on the comprehensive analysis of the graphs and experimental data, the average speed and acceleration of the carriage are significantly influenced by the load it carries. As the load increase, the average speed accelaeration decrease due to to the fundamental principle of physics. The power consumption of the carriage is directly impacted by the road conditions and the angle of the hills encountered. On a straight road, the power consumption follow the predictable pattern, with an initial increase to overcome inertia, follower by a decrease as the carriage decelerates. However, when traversing uphill, the power consumption rises sharply due to the additional gravitional force. Conversely, on downhill road, the power consumption remains relatively low as the carriage benefots from the gravitational froce assistingits motion.

Furthermore, the experiments reveal a linear relationship between power consumption and the angle of the hills, wuth steeper inclines demanding higher power requirements from the carriage's electrical system. The voltage drop analysis during the carriage's journey along the route road FTKE showcases the impact of extended operation on the electrical system's performance. This observation underscores the need for proper battery sizing, power management techniques, and system design considerations to mitigate voltage drops ad ensure reliable operation over extended periods or distances.

Overall, these findings provide valuable insights into the performance characteristics of the electrical carriage and highlight the crucial role of load, road conditions, terrain angles, and operational duration in determining its efficiency and effectiveness.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, this study provides a comprehensive understanding of the operation and assesment of an electrical carriage. The concept and rationale behind the project were introduced in Chapter 1, which underscored the necessity of a sustainable and efficient transportation option. The problem statement highlighted the complexities and challenges involved in designing and testing an electrical carriage with a motorized system. It emphasizes the importance of maximizing functionality while considering factors such as energy consumption and the behavior of linked circuits under various conditions to estimate system robustness. The need to identify potential stress points and electrical component issues through simulations is also underscored. Moreover, it stresses the necessity of further testing to ensure the design's efficiency, reliability, and safety, considering both controlled and uncontrolled environmental changes. The performance of the carriage in terms of acceleration, speed, and energy consumption across different distances and road conditions must be thoroughly assessed.

In Chapter 2, a comprehensive literature review was conducted to investigate the design structure, energy, performance analysis methodology, and extant research void in the field of electric rickshaw fabrication. The experimental testing approach was determined to be the most appropriate for this project due to its dependability and practicality in performance evaluation.

In Chapter 3, the methodology implemented for the assignment was described in detail. It involved the analysis and validation of the electrical carriage. By conducting experiments to evaluate the efficacy of electrical components and evaluating their functionality. The design process was scrupulously documented and included Fusion 360 renderings and manual outlines. In order to guarantee that the electrical components satisfy the specified specifications, they undergo testing. The carriage's efficacy can be considerably enhanced to ensure reliable and efficient operation in real-world scenarios by validating its comprehension of the power demands associated with various driving conditions.

The results of the performance analysis were presented in Chapter 4. Through the speed test, it became evident that there is a straightforward correlation between the load's mass and the average speed. Speeds were diminished as a consequence of heavier loads. During the power consumption test, it was observed that steeper inclines resulted in higher current usage due to increased power requirements. Several factors contribute to the performance predictions of the electrical carriage, including gravitational force, and rolling resistance. The path terrain significantly influences the vehicle's efficiency, with the driving range on horizontal paths exceeding that on uphill terrain due to higher power demands during uphill travel. By incorporating these considerations and specifications, predictions can be made regarding the electrical carriage's driving range, duration, and power consumption. Furthermore, different terrains were found to have distinct impacts on current consumption, underscoring the importance of terrain analysis in assessing electric vehicle performance.

Finally, the research comprehensively analyzed and validated the electrical carriage, yielding valuable insights into its performance across diverse scenarios. The findings underscore significant opportunities for enhancing power management and efficiency, thereby reinforcing the reliability and effectiveness of the carriage in practical applications. These insights contribute to advancing the development of electric vehicles, ensuring they meet rigorous standards of performance and sustainability in real-world conditions.

5.2 Recommendation

Integrating solar panels on the electrical carriage is an effective way to harness renewable energy and provide suppllementary power, thereby extending the range of the carriage. Solar panel can be mounted on the roof or other surfaces exposed to sunlight, converting solar energy into electrical power that can be used to charge the batteries or directly power the motor.

To enhance the comfort and safety of passengers and drivers in electrical carriage, it is recommended to incorporate a roof structure,. This addition will provide essential protection against overheating due to direct sunglight during drives.

Implementing this feature will ensure that electrical carriage offers a more reliable and enjoyable mode of transportation, especially in regions with high tempeeratures or intense sunlight.

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APPENDICES

APPENDIX A GANTT CHART FOR FINAL YEAR PROJECT

Table 10 Gantt chart FYP 1

Description	week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
FYP 1 Briefing														
Title Selection														
Meeting with SV														
Title Registration and Declaration form submission														
Search for related journals														
Background project, motivation, problem statement, objective and scope														
Literature Review														
Methodology														
Design														
Result and Priminary														
Submissions of Draft														
Attend Seminar for FYP 1														
Finalize Report progress														
Submission of Finalize Report Progress														

Table 11 Gantt Chart FYP 2

Description	week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
FYP 2 Briefing														
Meeting with SV														
Methodology														
Experimental setup														
Experiment speed and acceleration														
Experiment power consumption														
Experiment 3 different cases														
Experiment 3 different angle														
Experiment Laps														
Result and Discussion														
Submissions of Draft														
Attend Seminar for FYP 2														
Finalize Report progress														
Submission of Finalize Report														